



Remediation Program

LA-UR-03-1839

June 2003

ER2003-0199

GPP-03-032

Characterization Well R-20 Completion Report



Los Alamos NM 87545

Produced by the Groundwater Protection Program, Risk Reduction & Environmental Stewardship Division

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CONTENTS

1.0	INTRODUCTION	1
2.0	PRELIMINARY ACTIVITIES.....	2
3.0	SUMMARY OF DRILLING ACTIVITIES	3
3.1	Phase I Drilling.....	3
3.2	Phase II Drilling.....	6
4.0	SAMPLING AND ANALYSIS OF CORE, DRILL CUTTINGS, AND GROUNDWATER	8
5.0	BOREHOLE GEOPHYSICS	11
5.1	LANL-Supported Geophysical Logging	12
5.2	Schlumberger Geophysical Logging.....	13
6.0	LITHOLOGY AND HYDROGEOLOGY	14
6.1	Stratigraphy and Lithologic Logging	14
6.2	Groundwater Occurrence and Characteristics	16
7.0	WELL DESIGN AND CONSTRUCTION	16
7.1	Well Design.....	16
7.2	Well Construction.....	17
7.2.1	Well Installation	18
7.2.2	Annular Fill Placement	18
8.0	WELL DEVELOPMENT AND HYDROLOGIC TESTING.....	18
8.1	Well Development.....	18
8.2	Hydrologic Testing	21
8.3	Installation of Westbay™ Monitoring System.....	22
9.0	WELLHEAD COMPLETION AND SITE RESTORATION.....	22
9.1	Wellhead Completion.....	22
9.2	Geodetic Survey	22
9.3	Site Restoration	24
10.0	DEVIATIONS FROM THE R-20 SAP	24
11.0	ACKNOWLEDGEMENTS.....	24
12.0	REFERENCES.....	25

Appendixes

Appendix A	Activities Planned for R-20 Compared with Work Performed
Appendix B	Drill-Additive Product Specifications (CD attached to inside back cover)
Appendix C	Lithology Log
Appendix D	LANL Borehole Video Logs (CD attached to inside back cover)
Appendix E	Schlumberger Geophysical Report/Montage (CD attached to inside back cover)
Appendix F	Westbay™ Multi-Level Sampling Diagram (CD attached to inside back cover)
Appendix G	Waste Characterization Data

List of Figures

Figure 1.0-1	Location map, characterization well R-20	1
Figure 3.0-1	Well summary data sheet, characterization well R-20	4
Figure 3.0-2	Operations chronology diagram, characterization well R-20	5
Figure 7.2-1	As-built configuration diagram, characterization well R-20	19
Figure 9.1-1	Surface completion configuration diagram, characterization well R-20	23

List of Tables

Table 3.2-1	Fluid Additives Used, Characterization Well R-20	7
Table 4.0-1	Anion Concentrations in Alluvial Groundwater, Characterization Well R-20	8
Table 4.1-1	Hydrochemistry of Regional Aquifer Filtered Samples, Characterization Well R-20	9
Table 4.1-2	Hydrochemistry of Nonfiltered Regional Aquifer Samples, Characterization Well R-20 ..	11
Table 5.0-1	Borehole and Well Logging Surveys Conducted, Characterization Well R-20	12
Table 7.1-1	Well Screen Information, Characterization Well R-20	17
Table 7.2-1	Annular Fill Materials, Characterization Well R-20	20
Table 8.1-1	Development of Characterization Well R-20	21
Table 9.2-1	Geodetic Data, Characterization Well R-20	24

List of Acronyms and Abbreviations

AITH	array induction tool, Version H
ASTM	American Society for Testing and Materials
bgs	below ground surface
BMP	best management practice
CMR	combinable magnetic resonance
CNTG	compensated neutron tool, model G
COPC	chemical of potential concern
CVAA	cold vapor atomic absorption
DOT	Department of Transportation
DQO	data quality objective
DR	dual rotary
ECS	elemental capture spectroscopy
ESH	Environmental, Safety and Health
FMI	formation microimager
FSF	Field Support Facility (part of the Risk Reduction and Environmental Stewardship
GPS	global positioning system

GR	gamma radiation
hp	horsepower
HSA	hollow-stem auger
IC	ion chromatography
ICPES	inductively coupled plasma emission spectroscopy
ID	inner diameter
IRMS	isotope ratio mass spectrometry
LANL	Los Alamos National Laboratory
MDA	material disposal area
NAD 83	North American Datum, 1983
NGS	natural gamma spectroscopy
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
OD	outer diameter
psi	pounds per square inch
PFD	phosphate-free dispersant
PVC	polyvinyl chloride
QC	quality control
RC	reverse circulation
RRES	Risk Reduction and Environmental Stewardship (Division)
SAP	sampling and analysis plan
SMO	sample management office
SSHASP	site-specific health and safety plan
SVOC	semivolatile organic compound
TA	technical area
TD	total depth
TLD	triple detector lithodensity
TKN	total Kjeldahl nitrogen
UDR	universal drill rig
UR-DTH	under-reaming down-the-hole (hammer)
VOC	volatile organic compound
WCSF	waste characterization strategy form
WGII	Washington Group International, Inc.

Metric to US Customary Unit Conversions

Multiply SI (Metric) Unit	by	To Obtain US Customary Unit
kilometers (km)	0.622	miles (mi)
kilometers (km)	3281	feet (ft)
meters (m)	3.281	feet (ft)
meters (m)	39.37	inches (in.)
centimeters (cm)	0.03281	feet (ft)
centimeters (cm)	0.394	inches (in.)
millimeters (mm)	0.0394	inches (in.)
micrometers or microns (μm)	0.0000394	inches (in.)
square kilometers (km^2)	0.3861	square miles (mi^2)
hectares (ha)	2.5	acres
square meters (m^2)	10.764	square feet (ft^2)
cubic meters (m^3)	35.31	cubic feet (ft^3)
kilograms (kg)	2.2046	pounds (lb)
grams (g)	0.0353	ounces (oz)
grams per cubic centimeter (g/cm^3)	62.422	pounds per cubic foot (lb/ft^3)
milligrams per kilogram (mg/kg)	1	parts per million (ppm)
micrograms per gram ($\mu\text{g/g}$)	1	parts per million (ppm)
liters (L)	0.26	gallons (gal.)
milligrams per liter (mg/L)	1	parts per million (ppm)
degrees Celsius ($^{\circ}\text{C}$)	$9/5 + 32$	degrees Fahrenheit ($^{\circ}\text{F}$)

CHARACTERIZATION WELL R-20 COMPLETION REPORT

ABSTRACT

Characterization well R-20 was installed under implementation of the Los Alamos National Laboratory hydrogeologic work plan. Washington Group International, Inc., carried out drilling activities under a subcontract to Los Alamos National Laboratory (the Laboratory). The well is located east of Technical Area (TA)-18 on the south side of Pajarito Road in Pajarito Canyon. The primary purpose of this well is to provide hydrogeologic and water-quality data for regional groundwater near potential contaminant release sites at TA-54.

Hydrologic, geologic, geochemical, and geophysical information obtained during completion and subsequent sampling of well R-20 will provide data for the Laboratory hydrologic and geologic conceptual models and contribute to implementing a Laboratory-wide groundwater monitoring system. Monitoring this network of wells supports the Laboratory's Groundwater Protection Management Program Plan and will satisfy the requirements of the Pajarito Canyon work plan to characterize the regional aquifer in this area.

The R-20 borehole was drilled to a total depth of 1365 ft below ground surface using fluid-assisted and air-rotary and conventional mud-rotary drilling methods. Geologic strata encountered included alluvial sediments, the Tshirege Member of the Bandelier Tuff, deposits of the Cerro Toledo interval, ash flows and Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Cerros del Rio lavas, Puye Formation fanglomerates and pumiceous sediments, and sediments tentatively assigned to the Santa Fe Group.

No perched zones were encountered during drilling. The regional water table was encountered at a depth of 873 ft.

Three well screens were installed in well R-20 to measure vertical pressure gradients and to provide multiple water-quality monitoring ports in the regional aquifer. One screen was placed at the top of the regional aquifer and two were placed at depth within the aquifer. Well installation was completed on September 15, 2002. Two regional aquifer water samples were collected from the developed well and submitted for analysis. Although strontium-90 was detected near the minimum detection activity level, the absence of tritium suggests that the waters have not been impacted by Laboratory releases. The completed well was equipped with a Westbay™ multiport sampling system.

Initial coring attempts prior to deep drilling were successful only to a depth of 72.5 ft below ground surface. A separate boring was drilled adjacent to R-20 after well installation to collect remaining core samples. The borehole was advanced to a depth of 436 ft and core samples were collected to characterize the vertical distribution of potential contaminants beneath Pajarito Canyon. The borehole was plugged and abandoned after coring operations were completed.

1.0 INTRODUCTION

This completion report summarizes characterization well R-20 preparation, drilling, well construction, well development, and site completion activities conducted from July 9, 2002, to March 5, 2003. Well R-20 is located on the south side of Pajarito Road in Pajarito Canyon, 1225 ft east of water supply well PM-2 at Technical Area (TA)-18 (Figure 1.0-1). The well was installed as part of the "Hydrogeologic Workplan" (LANL 1998, 59599) to support of Los Alamos National Laboratory (LANL or the Laboratory) "Groundwater Protection Management Program Plan" (LANL 1996, 70215) and to meet the requirements of the "Work Plan for Pajarito Canyon" (LANL 1998, 58820). Data collection, testing, and well-development activities for R-20 were guided by the "Sampling and Analysis Plan (SAP) for the Drilling of Characterization Well R-16, R-20, R-21, R-23, and R-32 in the Vicinity of TA-54" (LANL 2002, 73390).

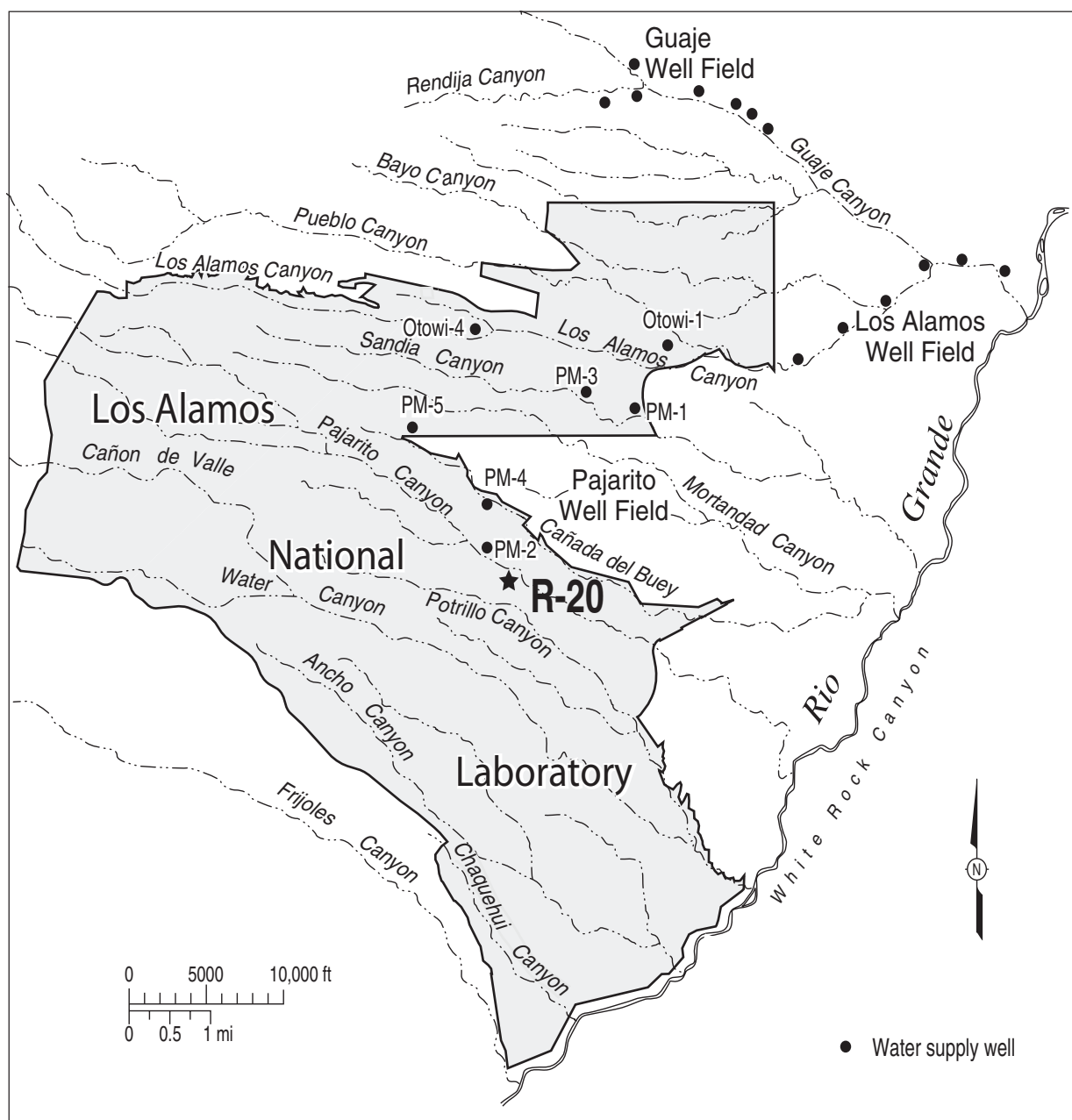


Figure 1.0-1. Location map, characterization well R-20

The project was funded by the Nuclear Weapons Infrastructure, Facilities, and Construction Program and installed by the Laboratory's Risk Reduction and Environmental Stewardship (RRES) Division. Washington Group International, Inc. (WGII), under contract to the Laboratory, was responsible for executing drilling activities.

Well R-20 will function primarily as a monitoring well between material disposal area (MDA) L at TA-54 and supply well PM-2. Well R-20 also will provide information about the extent of the capture zone at well PM-2. Water-quality, geochemical, hydrologic, and geologic data gathered during drilling and subsequent sampling will provide information about perched and regional groundwater in this part of Pajarito Canyon and the distribution of potential contaminants downgradient of Laboratory releases. These data will be used to update sitewide hydrologic and geologic conceptual models for the Laboratory.

Information presented in this report was compiled from field reports and activity summaries generated by Laboratory and subcontractor personnel. Geophysical data provided by Schlumberger, Inc. (Schlumberger) and geodetic survey results are included. This report focuses on operational activities associated with the drilling, sampling, and completion of well R-20. Detailed analysis and interpretation of geologic, geochemical, geophysical, and hydrologic data, included as part of previous well completion reports, will be discussed in separate technical documents to be prepared by the Laboratory.

2.0 PRELIMINARY ACTIVITIES

Preliminary activities at R-20 included administrative functions and site preparation. Appendix A compares these and other planned activities outlined in the R-20 SAP with actual work performed.

WGII received contractual authorization to start administrative preparatory tasks on June 6, 2002. As part of these tasks, WGII prepared a modification to existing site-specific health and safety plan (SSHASP) No. 271 to include well R-20. WGII also prepared the R-20 waste characterization strategy form (WCSF). The Laboratory prepared the sampling and analysis plan (SAP) to guide field personnel in executing R-20 field activities. The host facility, Facility Management Unit 80, signed a Facility Tenant Agreement to provide access and security control for R-20 activities.

A Readiness Review meeting was held on July 1, 2002, to discuss administrative documents, permits, agreements, and plans pertaining to the R-20 drill pad installation and drilling. The Groundwater Investigations Focus Area project leader signed the readiness review checklist on July 1, 2002, giving authorization to begin work.

K. R. Swerdfeger Construction, Inc., was subcontracted by WGII to conduct site preparation activities, including clearing and removing vegetation, modifying the access road, grading and compacting the drill pad, and constructing a lined cuttings-containment area. Site preparation began on July 9, 2002, and was completed on July 23, 2002.

The R-20 site initially was cleared of all vegetation. Construction of the drill pad involved leveling the 80-by 200-ft designated area with a grader and compacting several layers of base-course gravel. A 115-ft-long by 30-ft-wide by 14-ft-deep containment area was excavated along the south side of the drill pad and lined with a 6-mil polyethylene liner for storing drilling fluids. An 80-by 40-ft secondary fluids-containment area was constructed to accommodate three 20,000-gal. fluid-storage trailers and to store additional drilling fluids. Before the secondary containment facility was constructed, the perimeter of the area was bermed and lined with 6-mil polyethylene sheeting that overlapped the berms. The cuttings-containment area was fenced to control access. Safety barriers and signs were placed in appropriate locations. Office

and supply trailers, generators, and safety lighting equipment were moved to the site before drilling commenced.

3.0 SUMMARY OF DRILLING ACTIVITIES

Drilling activities were completed in two phases during August, September, and October 2002. Phase I drilling and core sampling was attempted by Stewart Brothers Drilling Company (Stewart Brothers) with a Failing F-10 auger rig equipped with 4.25-in.-inside diameter (ID), 9-in.-outside diameter (OD) hollow-stem augers (HSAs); the HSAs were equipped with a wire-line core retrieval system capable of collecting 3-in.-diameter by 5-ft-long core samples. Phase I drilling began on August 4, 2002. While coring through 68 ft of alluvium, the auger flights jammed several times, after coring down to only 72.5 ft below ground surface (bgs) by August 8, 2002. The Laboratory suspended coring operations until after well R-20 installation. Dynatec Drilling Company, Inc. (Dynatec), completed Phase I coring between October 16 and October 19, 2002, using a Foremost™ universal drill rig (UDR)-1000 equipped with a wire-line core retrieval system and a 5-ft-long core barrel to collect 2.5-in.-diameter core samples.

The goal of Phase I drilling was to collect continuous rock core samples for geologic characterization and to determine moisture, anion, stable isotope, radionuclide, metal, and tritium distributions in the upper section of the borehole. Planned total depth (TD) for Phase I drilling was approximately 450 ft bgs, or approximately 50 ft into the Cerros del Rio basalt. Coring was terminated at 436 ft bgs, 44 ft into the Cerros del Rio basalt.

Phase II drilling was conducted by Stewart Brothers using a Failing F-2500 drill rig and fluid-assisted air-rotary and mud-rotary drilling methods. Phase II objectives were to produce cuttings of encountered geologic formations, collect water samples from perched and regional groundwater zones and provide a borehole for geophysical measurements and well installation in the regional aquifer.

Figure 3.0-1 summarizes well data and depicts groundwater and geologic conditions encountered in well R-20. Sections 3.1 and 3.2 discuss Phase I and Phase II drilling activities, respectively, for R-20. Figure 3.0-2 summarizes the chronology of drilling and other related on-site activities.

3.1 Phase I Drilling

On August 3, 2002, Stewart Brothers mobilized the Failing F-10 drill rig and support equipment to the well R-20 site. On the following day, the borehole was advanced by HSA while attempting to core through the alluvium. At 32.5 ft bgs, the latching mechanism detached from the core barrel, leaving the core barrel in the borehole. After several unsuccessful attempts to retrieve the core barrel, Stewart Brothers moved the drill rig 10 ft to the east and started a new borehole. The offset boring was advanced to 32.5 ft, when coring resumed. Coring continued to 57.5 ft bgs on August 5, 2002, when Stewart Brothers set surface casing to seal off a shallow, saturated zone.

On August 6, 2002, Stewart Brothers reamed the second borehole to 37 ft bgs with a 12.25-in. auger bit, inserted 30 ft of 10.25-in.-ID surface casing, and pressure-grouted the casing in place. The cement was allowed to cure for 12 hr. The borehole then was reamed to 57.5 ft bgs and coring continued to 72.5 ft bgs, with poor core recovery during each interval.

Characterization Well R-20 Completion Report

Location: East of TA-18 on the south side of Pajarito Rd., east of the stream channel.

Survey coordinates (brass marker in NW corner of R-20 cement pad): x: 1637835 E y: 1759695 N (NAD 83) z: 6694.3 ft asl (NGVD 29)

Drilling: Conventional mud drilling, casing advance; air rotary core w/ wireline retrieval.

R-20 Start date: 08/15/02, end date: 09/06/02.

Coring start date: 10/16/02, end date: 10/19/02

Borehole R-20 drilled to 1365 ft. bgs. (T.D.).

Data collection:

Hydrologic properties: Field hydraulic test:

Constant Rate Injection Test on screen #1, screen #2, and screen #3

Cores/cuttings submitted for geochemical and contaminant characterization: (0)

Groundwater samples submitted for geochemical and contaminant characterization: (3)

Geologic properties: (12)

Mineralogy, petrography, and chemistry

Borehole logs from R-20:

Lithologic: 0-490 ft. and 785 ft.-1365 ft.

Borehole Video (LANL tool): 82-785 ft. (open hole).

Natural gamma + Induction (LANL tool):

0-80.2 ft. (cased), 80.2 ft.-785 ft. (cased).

Schlumberger Logs: 0-80.2 ft. (cased),

80.2-785 ft. (open hole): Array Induction, Litho

Density, Natural Gamma, Thermal/Epithermal

Neutron, Caliper, Combinable Magnetic

Resonance, and Elemental Capture Sonde.

Natural Gamma (LANL tool): 0-780 ft. (cased),

780-1365 ft. (open hole).

Schlumberger Logs: 0-780 ft. (cased), 780-

1365 ft. (open hole): Thermal/Epithermal Neutron,

Litho Density, Micro Imager, Array Induction,

and Natural Gamma.

Contaminants Detected in R-20 Water Samples: none

Well construction:

Drilling Completed: 09/06/02

Contract Geophysics: 08/26/02; 09/06/02

Well Constructed: 09/07/02-09/15/02

Well Developed: 09/15/02-12/22/02

Westbay Installed: 01/08/03-01/18/03

Casing: 4.5-in I.D. stainless steel with external couplings.

Number of Screens: 3

4.5-in I.D. pipe based, s.s. wire-wrapped with 0.010-in slots.

Screen (perforated pipe interval):

Screen #1 - 904.6 - 912.2 ft. bgs.

Screen #2 - 1147.1 - 1154.7 ft. bgs.

Screen #3 - 1328.8 - 1336.5 ft. bgs.

Well development consisted of wire brushing, bailing, chemical treatment, surging, and pumping.

Groundwater occurrence was determined for R-20 by recognition of first water produced while drilling, by borehole geophysics, and by borehole video. Static water levels were determined after the R-20 borehole was rested.

Groundwater samples collected from packed off screen intervals after well development.

Geologic contacts for R-20 were determined by examination of cuttings and interpretation of geophysical logs. Contacts may be refined by petrographic, geochemical, or mineralogic analysis of geologic samples.

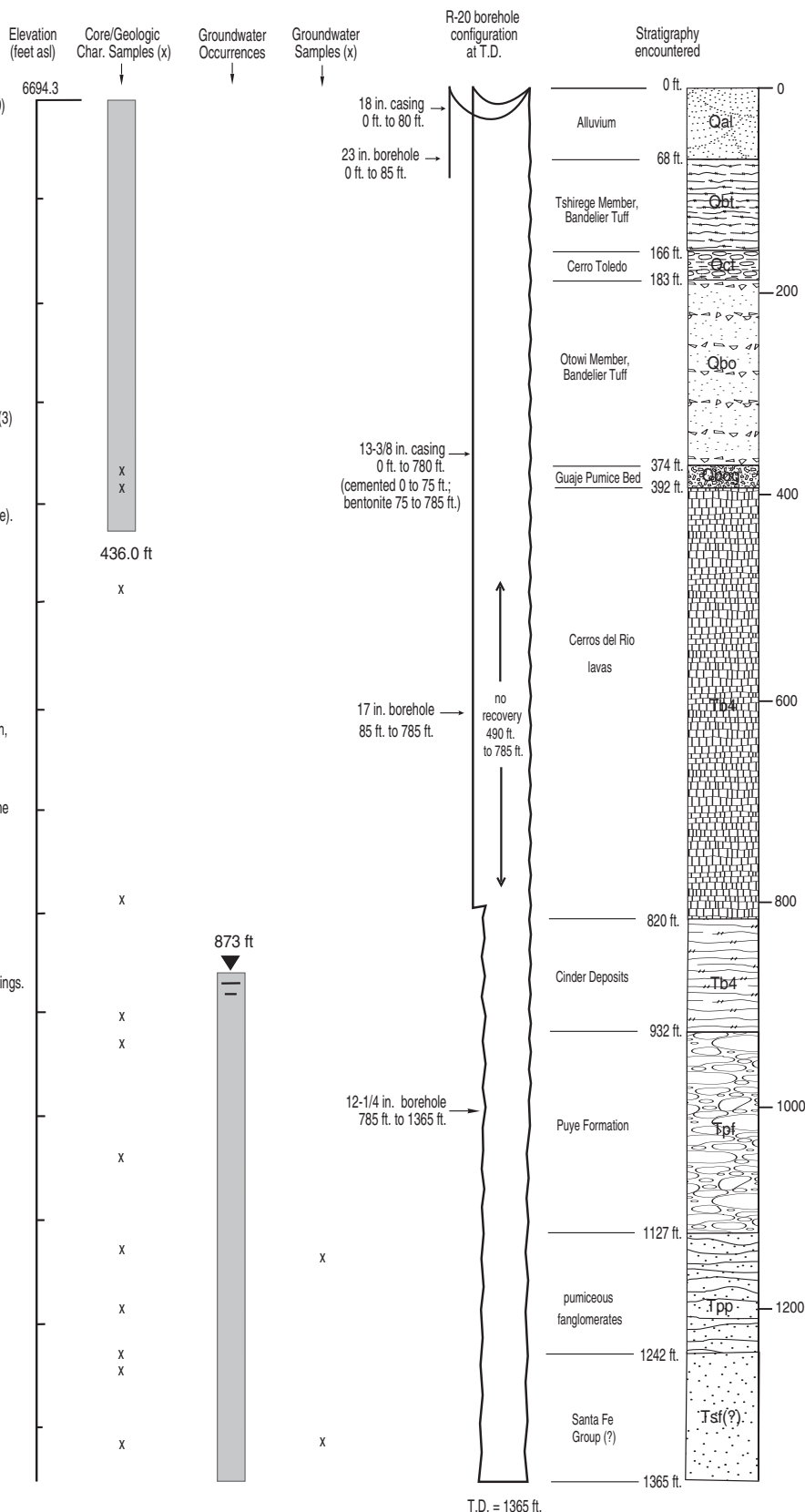


Figure 3.0-1. Well summary data sheet, characterization well R-20

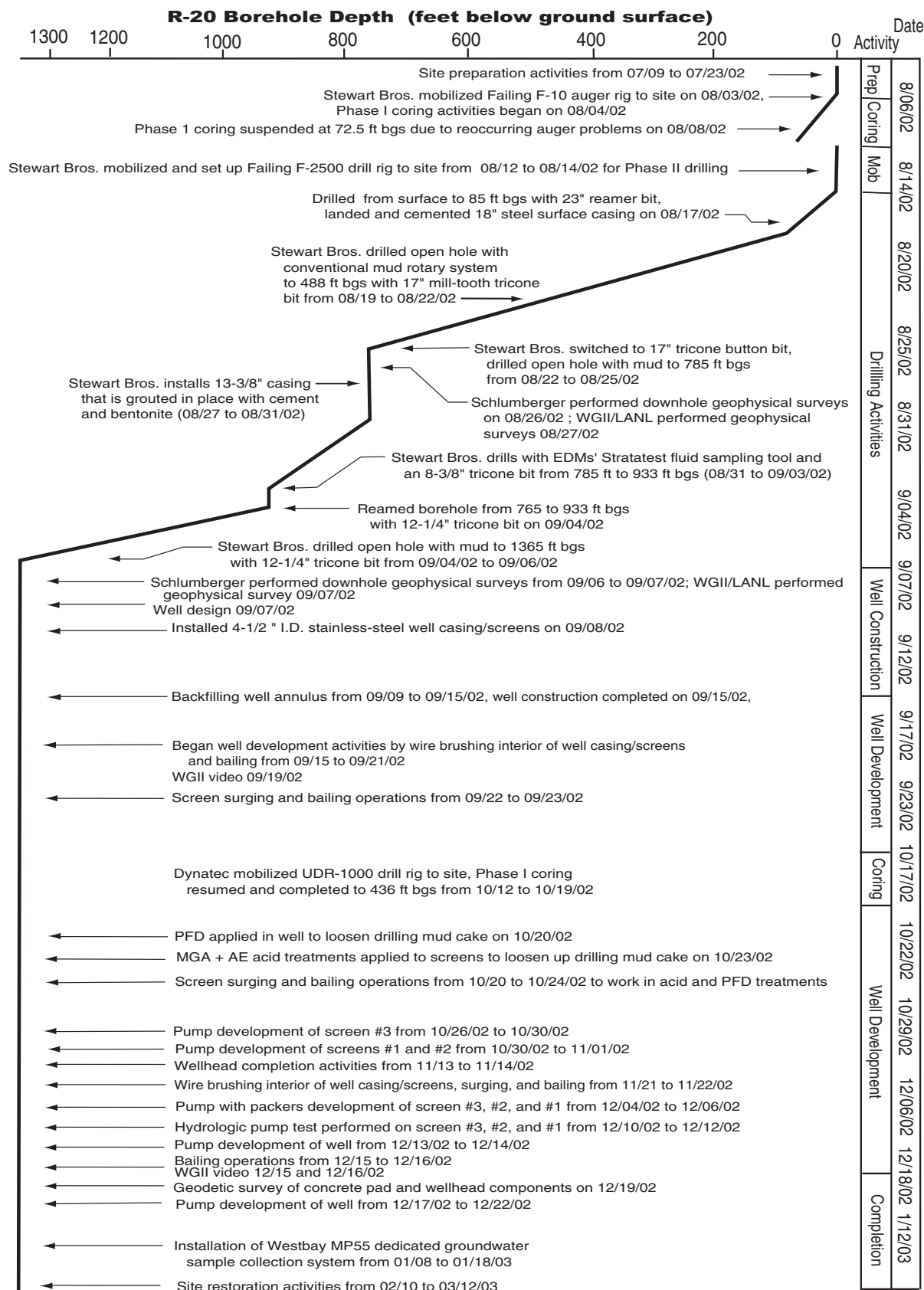


Figure 3.0-2. Operations chronology diagram, characterization well R-20

On August 7, 2002, Stewart Brothers advanced 18-in. augers into the Tshirege Member of the Bandelier Tuff to avoid the difficulties associated with coring through the alluvium. The temporary 10.25 surface casing was pulled from the borehole. During an attempt to advance the augers to 85 ft bgs, the augers separated at 50 ft bgs, leaving 35 ft of auger in the borehole between 50 and 85 ft bgs. On August 8, 2002, after unsuccessful attempts to fish out the augers that remained in the second borehole, it was abandoned and plugged by pumping cement grout through a tremie pipe and filling the borehole to ground surface. At this time, the Laboratory suspended coring operations until after Phase II drilling and well installation.

Dynatec resumed coring activities on October 12, 2002, after Stewart Brothers completed Phase II drilling and well installation. Dynatec mobilized the UDR-1000 drill rig to the site and advanced a new third borehole from ground surface to 75 ft bgs with an 8.75-in. tricone drill bit. While surface casing was being installed to approximately 50 ft bgs, the casing string parted at about 30 ft bgs. The casing was retrieved and subsequent attempts to ream and clear the borehole were unsuccessful. On October 14, 2002, Dynatec plugged and abandoned the third borehole by pouring hydrated bentonite chips into the borehole from 50 ft bgs to the surface.

Dynatec demobilized the UDR-1000 drill rig and mobilized the DR-24 drill rig to the site on October 15, 2002. Then, at the new fourth borehole location, 9.625-in. drill casing was advanced with a 10.75-in. under reaming down-the-hole hammer (UR-DTH) bit from ground surface to 70.5 ft bgs where the casing was landed. A mixture of water and E-Z Mud® was used to facilitate cuttings removal from the borehole. Following cuttings removal, 5.5-in. surface casing was installed within the 9.625-in. drill casing to 69 ft bgs. The annular space between the two casings was backfilled with 0.375-in. bentonite chips as the 9.625-in. drill casing was removed.

On October 16, 2002, the DR-24 drill rig was removed from the site and the UDR-1000 rig was mobilized to the site. The borehole was advanced to 72.5 ft and coring resumed using a 5-ft-long, 2.5-in.-ID core barrel; coring concluded at 436 ft bgs on October 19, 2002. The cored hole was backfilled with Pelplug® bentonite pellets to 102 ft bgs, Hole-Plug® bentonite chips to 27 ft bgs, cement to 2 ft bgs and gravel to ground surface. Phase I operations concluded on October 19, 2002.

3.2 Phase II Drilling

On August 12, 2002, Stewart Brothers mobilized a Failing F-2500 drill rig and support equipment to the site. Following the unsuccessful attempts to core, a new borehole was started. The borehole for Phase II was drilled using conventional mud-rotary methods. Various additives were mixed with municipal water to improve borehole stability, minimize fluid loss, and facilitate cuttings removal from the borehole. The conventional mud fluid mixture at R-20 typically consisted of municipal water mixed with varying amounts of soda ash, QUICK-GEL®, LIQUI-TROL™, and QUICK-FOAM® (Appendix B). Lost circulation material (Magma-Fiber and N-seal) was used as needed in the mud mixture to maintain or regain circulation within the borehole (Table 3.2-1).

Stewart Brothers provided the equipment used to mix and circulate drilling fluids. This equipment included a mixing tank and pump assembly, a generator to power the mixing unit, and a shaker unit for removing solids from the discharged drilling fluids. From August 12 to August 15, 2002, Stewart Brothers positioned drilling-fluid mixing equipment and conducted rig maintenance.

Table 3.2-1
Fluid Additives Used, Characterization Well R-20

Additive	Amount	Unit of Measure
Interval Drilled (0–780 ft)		
Water	48,300	gal.
QUICK-GEL®	26,565	lb
LIQUI-TROL™	135	gal.
QUICK FOAM®	483	gal.
Soda ash	536	lb
Interval Drilled (780–1365 ft)		
Water	37,100	gal.
QUICK-GEL®	7,000	lb
LIQUI-TROL™	87	gal.
Pac-L	200	lb
N-Seal	100	lb
Magma Fiber	620	lb

From August 15 through 17, 2002, Stewart Brothers installed an 18-in. steel conductor casing by advancing a borehole through the alluvium with a 23-in. tricone bit from ground surface to 85 ft bgs. The conductor casing was landed 12 ft into the Tshirege Member of the Bandelier Tuff and cemented in place on August 17, 2002. On August 22, 2002, open-hole drilling was conducted with a 17-in. mill-tooth tricone bit from 85 to 488 ft bgs through intervals of the Tshirege Member of the Bandelier Tuff, the Cerro Toledo, the Otowi Member of the Bandelier Tuff (including the Guaje Pumice Bed), and into the Cerros del Rio basalt. Stewart Brothers then switched to a 17-in. tricone button bit to increase the drilling rate in the basalt. Drilling continued from 488 ft bgs, with sporadic loss of fluid circulation, down to 500 ft bgs. On August 24 and 25, 2002, drilling advanced from 500 to 785 ft bgs with no circulation of cuttings return to the surface. No cuttings were recovered from 490 to 785 ft bgs.

On August 27, 2002, a 13.375-in. conductor casing was installed to a depth of 780 ft bgs; the annulus between 552 and 780 ft bgs was grouted with cement to seal off lower portions of the borehole that contributed to the loss of drilling fluid. The upper portion of the annulus was backfilled with a combination of Quick-Grout® bentonite grout, Pelplug® bentonite pellets, and Hole-Plug® bentonite chips to 79 ft bgs. The annular interval above 79 ft bgs was backfilled with cement on August 31, 2002.

At the Laboratory's request, EDM Systems (USA), a German firm, conducted a demonstration of Stratatest™, from August 31 to September 3, 2002. This formation fluid-sampling and -testing tool is designed to operate just behind a drill bit as part of the drill stem. The tool is intended to aid in collecting representative groundwater samples from discrete water-production zones by placing a sand pack above and below a 5-ft-long target interval. With the sand packs in place, water is pumped to develop the isolated zone. A groundwater sample is collected after the zone has been adequately developed. During drilling with the Stratatest™ tool, the borehole was advanced from 785 to 933 ft bgs using an 8.375-in. tricone bit. No groundwater samples were collected with the Stratatest™ tool.

On September 4, 2002, Stewart Brothers continued mud-rotary drilling operations with a 12.25-in. tricone bit. The borehole was reamed through slough from 785 to 933 ft bgs and then advanced to 1365 ft bgs,

where TD was called in Santa Fe Group sediments on September 6, 2002. Drilling activities for Phase II were completed on September 7, 2002.

4.0 SAMPLING AND ANALYSIS OF CORE, DRILL CUTTINGS, AND GROUNDWATER

Core samples were collected and analyzed for anions using ion chromatography (IC) and for radionuclides using counting techniques for characterization purposes. Thirteen core samples were collected from the vadose zone during drilling from 9.5 to 434.0 ft bgs. Approximately 500 to 1000 g of core or cuttings samples were placed in appropriate sample jars in protective plastic bags before they were analyzed by EES-6 and General Engineering Laboratories (GEL). The results will be reported in an investigation report for the TA-54 wells.

Table 4.0-1
Anion Concentrations in Alluvial Groundwater,
Characterization Well R-20

Anion	Concentration (mg/L)
Cl	33.0
NO ₃ (as NO ₃)	16.1
SO ₄	9.89

Drill cuttings were collected at 5-ft intervals as specified in the R-16, R-20, R-23, R-32 SAP. A portion of the cuttings was sieved (at >#10 and >#35 mesh) and placed in chip tray bins along with an unsieved portion. These samples were used to prepare a lithologic log (Appendix C). The remaining cuttings were placed in ziplock bags and set in core boxes for curation. Before curation, 12 sample splits were removed for use in mineralogy, petrography, and geochemical analyses.

Alluvial groundwater was encountered at 17.2 ft bgs. A sample was collected and analyzed for anions; results are provided in Table 4.0-1. No perched intermediate groundwater was encountered at well R-20 during fluid-assisted drilling. Regional groundwater was encountered at 837 ft bgs on September 4, 2002.

Geochemistry of Sampled Waters

Two regional aquifer water samples were collected from the developed well and were analyzed for a limited suite of constituents. These samples were collected from screen 2 (1147.1 to 1154.7 ft) and from screen 3 (1328.8 to 1336.5 ft). Screen 1 (904.6 to 912.2 ft) did not produce a sufficient volume of water to permit sampling. The samples were collected at depths of 1151 and 1336 ft primarily to determine if potential contaminants were present in the regional aquifer. Major potential contaminants of concern at R-20 include mobile solutes such as nitrate, perchlorate, uranium, and tritium.

Groundwater samples analyzed for inorganic and organic chemicals, tritium, and other radionuclides were collected by using a submersible pump and packers. Temperature, turbidity, pH, alkalinity, and specific conductance were determined on the site. Both filtered (metal, trace-element, and major cation and anion) and nonfiltered (radionuclide, organic-compound, and stable-isotope) samples were collected for chemical and radiochemical analysis. Aliquots of the samples were filtered through a 0.45- μ m Gelman filter. Samples were acidified with analytical-grade nitric acid to a pH of 2.0 or less for metal and major ion analyses. All groundwater samples collected in the field were stored at 4°C until they were analyzed. Alkalinity was determined in the field using standard titration techniques.

Groundwater samples were analyzed by EES-6 using techniques specified in the US Environmental Protection Agency (EPA) SW-846 manual (available at <http://clu-in.org/char1.cfm>).

IC was the analytical method used for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. Mercury was analyzed by cold vapor atomic absorption (CVAA). Inductively coupled (argon) plasma emission spectroscopy (ICPES) was the analytical method used for calcium, magnesium, potassium, silica, and sodium. Aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, selenium, silver, thallium, vanadium, uranium, and zinc were analyzed by inductively coupled (argon) plasma mass spectrometry (ICPMS).

Radionuclide activity in groundwater was determined by electrolytic enrichment for tritium; alpha spectrometry was the analytical method used for americium, plutonium, and uranium isotopes; gas proportional counting was used for strontium-90; liquid scintillation was used for technetium-99; and gamma spectrometry was used for cesium-137 and other gamma-emitting isotopes. Contract laboratories that conducted this work were GEL (radionuclides) and the University of Miami (low-level tritium). Stable isotopes of oxygen (oxygen-18 and oxygen-16, $\delta^{18}\text{O}$) and hydrogen (hydrogen and deuterium, δD) were analyzed by Geochron Laboratories (Cambridge, Massachusetts) using isotope ratio mass spectrometry (IRMS).

The precision limits (analytical error) for major ions and trace elements generally were less than $\pm 10\%$ using ICPES and ICPMS. Core samples were collected; analytical results (for inorganics and radionuclides) will be provided in an investigative report.

Tables 4.1-1 and 4.1-2 provide screening analysis results for the two groundwater samples collected from the Cerros del Rio lavas and pumiceous fanglomerates. Although strontium-90 was detected near the minimum detection activity level, the absence of tritium suggests that the waters have not been impacted by Laboratory releases.

Table 4.1-1
Hydrochemistry of Regional Aquifer Filtered Samples, Characterization Well R-20

Parameter and Analyte	Cerros del Rio Lavas Screen 2 (1151 ft bgs)	Pumiceous Fanglomerates Screen 3 (1336 ft bgs)
Field Parameter		
pH	7.04	6.84
Temperature (°C)	21.8	22.5
Specific conductance ($\mu\text{S}/\text{cm}$)	128	100
Turbidity (NTU)	2.84	43.7
Analyte		
Alkalinity (mg CaCO_3/L)	54	36
Al (mg/L)	0.011	0.013
Sb (mg/L)	[0.001], U	[0.001], U
As (mg/L)	0.0017	0.0021
B (mg/L)	0.008	0.010
Ba (mg/L)	0.031	0.033
Be (mg/L)	[0.001], U	[0.001], U
HCO_3 (mg/L)	66	44

Table 4.1-1 (continued)

Parameter and Analyte	Cerro del Rio Lavas Screen 2 (1151 ft bgs)	Pumiceous Fanglomerates Screen 3 (1336 ft bgs)
Br (mg/L)	0.03	0.03
Cd (mg/L)	[0.001], U	[0.001], U
Ca (mg/L)	9.34	7.43
Cl (mg/L)	2.13	2.42
ClO ₄ (mg/L)	[0.002], U	[0.002], U
Cr (mg/L)	0.0039	0.0013
Co (mg/L)	[0.001], U	0.0029
Cu (mg/L)	0.0036	0.0026
F (mg/L)	0.28	0.55
Fe (mg/L)	0.09	0.22
Pb (mg/L)	0.0004	0.0003
Mg (mg/L)	2.21	1.72
Mn (mg/L)	0.042	0.110
Hg (mg/L)	0.00008	0.00006
Mo (mg/L)	0.0016	0.0026
Ni (mg/L)	0.0043	0.0037
NO ₃ (mg/L) (as N)	0.01	[0.005], U
NO ₂ (mg/L) (as N)	[0.005], U	[0.005], U
C ₂ O ₄ (mg/L) (oxalate)	[0.02], U	[0.02], U
PO ₄ (mg/L) (as P)	0.60	2.21
K (mg/L)	2.35	2.05
Se (mg/L)	[0.001], U	[0.001], U
Ag (mg/L)	[0.001], U	[0.001], U
Na (mg/L)	12.3	13.8
SiO ₂ (mg/L)	81.1	89.2
Sr (mg/L)	0.092	0.062
SO ₄ (mg/L)	2.78	4.89
Tl (mg/L)	[0.001], U	[0.001], U
U (mg/L)	0.0007	0.0003
V (mg/L)	0.005	0.004
Zn (mg/L)	0.49	0.79
TDS (mg/L) (calculated)	180	170

Notes: 1. All samples collected December 5, 2002.

2. U = not detected.

3. Silica concentrations were calculated from measured silicon (ICPES).

4. Bicarbonate concentrations were calculated from measured alkalinity.

Table 4.1-2
Hydrochemistry of Nonfiltered Regional Aquifer Samples, Characterization Well R-20

Parameter and Analyte	Cerro del Rio Lavas Screen 2 (1151 ft bgs)	Pumiceous Fanglomerates Screen 3 (1336 ft bgs)
Tritium (pCi/L)	[0.32], U	[0.19], U
Am-241 (pCi/L)	[-21.9], U	[3.71], U
Cs-137 (pCi/L)	[-1.67], U	[-0.044], U
Gross alpha (pCi/L)	[0.98], U	[2], U
Gross beta (pCi/L)	1.51	1.59
Gross Gamma (pCi/L)	[115], U	[102], U
Pu-238 (pCi/L)	[0.002], U	[0.005], U
Pu-239,240 (pCi/L)	[-0.005], U	[-0.005], U
Sr-90 (pCi/L)	0.280±0.083, MDA, 0.2	0.351±0.100, MDA, 0.11
Tc-99 (pCi/L)	[-0.69], U	[2.37], U
U-234 (pCi/L)	0.369	0.317
U-235 (pCi/L)	[0.0248], U	[0.0271], U
U-238 (pCi/L)	0.198	0.157
TOC (mgC/L)	2.13	2.77
Acetone (µg/L)	60.5	17.5
Toluene (µg/L)	11.3	4.8
δD (‰)	-79	-81
δ ¹⁸ O (‰)	-11.4	-11.3

Notes: 1. All samples collected December 5, 2002.

2. U = not detected.

3. ‰ = permil.

4. MDA = minimum detectable activity.

5. NTU = nephelometric turbidity unit.

6. TOC = total organic carbon.

7. Standard deviation is 1 sigma.

5.0 BOREHOLE GEOPHYSICS

WGII (using Laboratory tools) and Schlumberger provided geophysical logging services at R-20. Table 5.0-1 lists borehole and well logging surveys performed at R-20.

Table 5.0-1
Borehole and Well Logging Surveys Conducted, Characterization Well R-20

Operator	Date	Method	Cased Footage	Open-Hole Interval (ft bgs)	Remarks
Schlumberger	August 26, 2002	Logging suite ^{a,b}	0–80	80–785	Conducted in borehole prior to installation of 13.375-in. thin-walled conductor casing.
WGII/LANL	August 27, 2002	Video, natural gamma, induction	0–80	80–785	Conducted in borehole prior to installation of 13.375-in. thin-walled conductor casing.
Schlumberger	September 6–7, 2002	Logging suite ^{b,c}	0–780	780–1365	Conducted in borehole prior to design and installation of the well casing.
WGII/LANL	September 7, 2002	Natural gamma	0–780	780–1365	Conducted in borehole prior to design and installation of the well casing.
WGII/LANL	November 19–20, 2002	Video, natural gamma	0–1353.3	NA ^d	Video log run to document and verify well screen intervals and interior condition of the well. Natural gamma tool was run to verify backfill placement.
WGII/LANL	December 15, 2002	Video	0–1353.3	NA	Video log run to document and verify interior condition of the well during development.
WGII/LANL	December 16, 2002	Video	0–1353.3	NA	Video log run to 1351 ft bgs to document and verify interior condition of the well prior to Westbay™ installation.

^a First suite of Schlumberger borehole logging surveys on August 26, 2002, included array induction, combinable magnetic resonance, triple detector lithodensity (TLD), sonic borehole caliper, elemental capture sonde, thermal/epithermal compensated neutron log, and natural gamma.

^b Array induction imager, combinable magnetic resonance, formation microimager, and borehole caliper were run only in the open portion of the borehole.

^c Second suite of Schlumberger borehole logging surveys included array induction imager, formation microimager, TLD, thermal/epithermal compensated neutron log, and natural gamma.

^d NA = Not applicable; video and natural gamma logs were performed inside the well casing.

5.1 LANL-Supported Geophysical Logging

On five days between August 27 and December 16, 2002, WGII ran natural gamma, induction, and/or video logs in borehole R-20 using down-hole logging tools provided by the Laboratory. Three natural gamma logs were run. The first two were run to provide lithologic and stratigraphic information that complemented data gathered from cuttings. The third was run to verify and document the placement of annular backfill materials. An induction log also was run with the first natural gamma log. Four video logs were run to record lithologic and hydrogeologic features and to observe and document the condition of the interior of the well during and after development.

Natural gamma logs have proven successful in discriminating between geologic units with varying concentrations of uranium, thorium, and potassium. The induction tool has been useful in differentiating

between formations with different conductivity and resistivity. The first gamma log was run inside the 18-in. surface casing from the surface to 80 ft bgs and in the open borehole from 80 to 785 ft bgs prior to installation of the 13.375 in. thin-walled steel conductor casing. The induction log also was run at this time. The second gamma log was run with the 18-in. surface casing in place from surface to 80 ft bgs and the 13.375-in. conductor casing from ground surface to 780 ft bgs, and in the open borehole from 780 to 1365 ft bgs. The third natural gamma log was run inside the well to a depth of 1353 ft bgs. Measurements of natural gamma activity were obtained every 0.1 ft as the logging tool was raised upward in the hole at a rate of about 15 ft/min.

The first video log was run before the first natural gamma log (Table 5.0-1) to evaluate borehole stability before the natural gamma and induction logging tools were deployed. This first video log was run to record stratigraphic, geologic, and hydrologic features present in the open portion of the borehole. Appendix D (on a CD on the inside back cover of this report) contains the video log of the open borehole. Three additional video logs were run as a quality-control procedure to verify and document well construction and to inspect the condition of casing and screens during and after well development but before installation of the Westbay™ system.

5.2 Schlumberger Geophysical Logging

Schlumberger personnel conducted borehole geophysical logging in the R-20 borehole on August 26, 2002, and again on September 6 through 7, 2002, in the R-20 borehole. The logging tools run for each suite are presented as notes to Table 5.0-1. The first suite of logging surveys was run inside the 18-in. surface casing from surface to 80 ft bgs and in open borehole from 80 to 785 ft bgs. The second suite of logging surveys was run before well design and construction, with the 18-in. surface casing in place from the surface to 80 ft bgs, the 13.375 in. conductor casing from ground surface to 780 ft bgs, and in open borehole from 780 to 1365 ft bgs.

The primary purpose of the Schlumberger logging was to characterize conditions in the hydrogeologic units that were penetrated by the R-20 borehole, with primary emphasis on determining the moisture distribution in the vadose zone and in the regional aquifer, measuring flow capacity, and gathering lithologic/stratigraphic data. Secondary objectives included evaluating borehole geometry and assessing the degree of drilling-fluid invasion along the borehole wall.

The Schlumberger suite of geophysical logging tools included the following:

- Array Induction Tool, Version H (AITH™) measures formation electrical resistivity and borehole fluid resistivity to evaluate drilling fluid invasion into the formation and determines the presence of moist zones far from the borehole wall.
- Combinable Magnetic Resonance (CMR™) measures the nuclear magnetic resonance response of the formation, evaluates total and effective water-filled porosity of the formations near the borehole wall, and estimates pore-size distribution and hydraulic conductivity.
- Triple detector LithoDensity (TLD™) measures formation bulk density related to formation porosity, photoelectric effects related to lithology, and borehole diameter using a single-arm caliper.
- Thermal/Epithermal Compensated Neutron Tool, Model G (CNTG™), measures volumetric water content beyond the casing to evaluate formation moisture content and porosity.
- Elemental Capture Sonde (ECS™) measures elemental weight concentrations of a variety of elements to characterize formation mineralogy, lithology, and water content.

- Fullbore Formation Micro Imager (FMI™) measures electrical conductivity images of the borehole wall and the borehole diameter with a two-axis caliper, thus evaluating geologic bedding and fracturing, including strike-and-dip of these features, fracture apertures, and rock textures.
- Digital Sonic Logging Tool (DSLTL) measures acoustic compressional (P-wave) velocity to correlate seismic velocity with depth for calibrating surface seismic surveys.

Additionally, a calibrated natural gamma tool was used to record gross natural gamma activity with every logging method to correlate depth runs between each survey conducted.

The Schlumberger logging summary report for borehole R-20 and the geophysical logs for all Schlumberger methods, compiled as a montage, are contained in Appendix E (see CD attached to the inside back cover of this report).

6.0 LITHOLOGY AND HYDROGEOLOGY

A preliminary assessment of the hydrogeologic features encountered in borehole R-20 is presented below, including a description of the geologic units identified during cuttings-characterization. Groundwater occurrence is discussed and evaluated by drilling evidence and geophysical data.

6.1 Stratigraphy and Lithologic Logging

Rock units and stratigraphic relationships, interpreted primarily from examination of drill-cuttings samples and interpretation of geophysical data, are discussed in order of younger to older units encountered. Such interpretations may be refined upon further analysis of petrographic, geochemical, mineralogical, and geophysical logging. A field-generated lithology log for R-20 can be found in Appendix C.

Alluvium and Soil (0 to 68 ft bgs)

Unconsolidated dacite and tuffaceous sands and gravels, derived from the Tschicoma Formation and the Bandelier Tuff, were noted in the interval from 0 to 68 ft bgs. Samples indicate that these sediments are predominantly dacite and minor rhyodacite clasts in a matrix of quartz and sanidine crystals. The sediments represent alluvial deposits in Pajarito Canyon.

Bandelier Tuff (68 to 392 ft bgs)

The Quaternary-age Bandelier Tuff occurs in the interval from 68 to 392 ft bgs (Appendix C). Units that are represented in cuttings samples include the Tshirege Member, the Cerro Toledo interval (an informal unit), and the Otowi Member, including the Guaje Pumice Bed.

Tshirege Member of the Bandelier Tuff, Undivided (68 to 166 ft bgs)

The Tshirege Member of the Bandelier Tuff is made up of a succession of rhyolite ash-flow tuffs (Broxton and Reneau 1995, 49726); rocks of this unit were encountered from 68 to 166 ft bgs in R-20. Subunits of the Tshirege Member were not identified on preliminary analysis of the R-20 data. Cutting samples in the upper one-third of the Tshirege Member are lithic-rich, with lithics composed predominantly of gray porphyritic dacite and minor rhyolite. The Tshirege Member is not typically lithic-rich at other locations, and the lithic-rich nature of the cuttings may be the result of ash and pumice separation from lithic-rich concentrates by circulating drilling fluids. Pumice predominates as the major constituent in the lower two-thirds of the section. Pumice fragments, typically 40% to 90% by volume, are unaltered or variably altered

to clay, producing an earthy texture. The lower part of the Tshirege Member also contains variable percentages of dacite lithics and quartz and sanidine crystals. The Tsankawi Pumice Bed, a 2- to 3-ft-thick fall deposit that typically occurs at the base of the Tshirege Member, could not be identified in the drill cuttings.

Cerro Toledo Interval (166 to 183 ft bgs)

The Cerro Toledo interval was encountered from 166 to 183 ft bgs. Cuttings indicate that the interval is composed of subrounded dacitic and rhyodacitic clasts (85% to 95% by volume), with minor percentages of pumice and detrital quartz and sanidine crystals.

Ash Flows of the Otowi Member of the Bandelier Tuff (183 to 374 ft bgs)

Ash-flow tuffs of the Otowi Member were intersected in the borehole from 183 to 374 ft bgs. Cuttings suggest that the Otowi Member is poorly welded to nonwelded and lithic- and pumice-rich. Coarse chip samples contain highly variable percentages of volcanic lithics, composed of dacite, silicified dacite, and rhyodacite, and white-to-orange vitric and clay-altered pumice. Finer-sieved sample fractions typically contain intermediate volcanic lithics, pumice fragments, and quartz and sanidine crystals in roughly equal proportions.

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff (374 to 392 ft bgs)

The Guaje Pumice Bed of the Otowi Member is a pumice-fall deposit that regionally forms the basal unit of the Bandelier Tuff. Borehole R-20 intersected the Guaje Pumice Bed from 374 to 392 ft bgs. Drill cuttings from this interval indicate that the unit is nonwelded and made up of vitric to slightly clay-altered pumice (60% to 80% by volume) with subordinate amounts of pinkish and gray dacite lithics and quartz and sanidine crystals.

Cerros del Rio Lavas (392 to 932 ft bgs)

The R-20 borehole encountered lavas and cinder deposits of the Cerros del Rio lavas in a 540-ft thick interval from 392 to 932 ft bgs (Appendix C). The upper part of the Cerros del Rio section, from 392 to 820 ft bgs, is composed of a series of basaltic flows separated by layers of scoriaceous breccia. Identification of this subunit is uncertain in part because fluid circulation was lost during drilling and no samples were recovered in the interval from 490 to 785 ft bgs. Cuttings from recovered samples suggest that at least three lava flows may be represented.

Two flow units occur in the interval from 392 to 490 ft bgs, both characterized as slightly porphyritic with sparse olivine phenocrysts in an aphanitic groundmass. A 5- to 10-ft thick layer of oxidized scoriaceous basalt is evident at the base of both flows. The upper of these two lavas exhibits partial alteration in the form of iron oxides and local clay development on fractures. Generally stronger rock alteration in the lower flow is evidenced by opaque iddingsite replacement of olivine and alteration of groundmass minerals that intensifies with depth. A third lava flow that lacks olivine phenocrysts and exhibits stronger alteration and bleaching is evident in the interval from 785 to 820 ft bgs.

Cuttings suggest that the basal Cerros del Rio section, from 820 to 932 ft bgs, is made up of basalt, basaltic scoria, and local volcanoclastic sediments. Chip samples contain massive aphyric basalt and black vitric scoria. Samples from the lowermost part of this interval contain downward-increasing percentages of subrounded detrital dacite, pumice, white clay, and minor quartzite and granitic lithics.

Puye Formation (932 to 1242 ft bgs)

The Pliocene Puye Formation, encountered from 932 to 1242 ft bgs (Appendix C), is represented by two volcanoclastic fanglomerate facies. The upper facies is composed predominantly of dacite-rich detritus, and the lower facies contains abundant pumice.

Dacite-rich Puye Formation sediments occur in the interval from 932 to 1127 ft bgs. Cuttings indicate clay-rich volcanoclastic sands and gravels containing porphyritic pink and gray dacites (commonly 80% to 95% by volume) as major constituents, with minor amounts of basalt, pumice, and quartzite. Preserved fragments of volcanoclastic sandstone indicate that these sediments are at least moderately indurated. The Puye Formation facies encountered from 1127 to 1242 ft bgs is interpreted as a pumiceous fanglomerate. Cuttings show that this interval contains significant percentages of white clay-altered pumice fragments (typically in the range of 20% to 50% by volume) in addition to clasts of dacite, minor basalt, and up to 3% quartzite. The pumiceous unit is included here with the Puye Formation, but this unit is poorly known and its stratigraphic assignment is uncertain.

Santa Fe Group (?) Sediments (1242 to 1365 ft bgs)

Volcanoclastic sand and gravel deposits, encountered from 1242 ft bgs to the bottom of the borehole at 1365 ft bgs (Appendix C), are tentatively assigned to the Santa Fe Group. Sediments in this interval are primarily composed of subrounded dacite and rhyodacite clasts that typically make up 80% to 95% by volume of the coarse-sized cuttings. Subordinate lithic constituents include scoriaceous basalt, white clay-altered pumice, and up to 5% quartzite. Quartzite particle surfaces are commonly smooth and frosted.

6.2 Groundwater Occurrence and Characteristics

When the SAP was written, it was expected that the regional water table at R-20 would be encountered at around 854 ft bgs in the Puye Formation. Perched water was also expected, but the SAP did not indicate specific depths. Alluvial waters were encountered at approximately 17 ft bgs. This zone produced enough water to fill 40 ft of the 10-in.-diameter borehole and surface casing was installed to seal off the zone before Phase I coring could continue.

The regional water table was encountered on August 27, 2002, in cinder deposits of the Cerros del Rio lavas. After circulating drilling fluids from the borehole, the first water-level measurement indicated a depth to water of 873 ft bgs. At this time the conductor casing was set at 780 ft bgs, and the borehole was open to 913 ft bgs. A composite groundwater level was measured again at 857.7 ft bgs on September 17, 2002, after well construction but before well development. Near the end of well development activities, on December 20, 2002, the composite groundwater level was measured at 832.3 ft bgs, after a 14-hr stabilization period.

7.0 WELL DESIGN AND CONSTRUCTION

Sections 7.1 and 7.2 describe R-20 well design and construction, respectively.

7.1 Well Design

The design for well R-20 was completed jointly by the Laboratory and WGII, in consultation with the New Mexico Environment Department (NMED) and the US Department of Energy (DOE). Information gathered from geophysical logs, video logs, borehole geologic samples, water-level data, field water-quality data,

and drillers' observations was analyzed by the Groundwater Integration Team to plan screen placement intervals for the well.

The final well design specified three screens in the regional aquifer and installation of a Westbay™ sampling system. No intermediate perched zones were identified; therefore, no screens were placed above the regional water table. The planned and actual screen intervals are given in Table 7.1-1. The proposed well design supports the data quality objectives (DQOs) for the regional aquifer, including installing a monitoring well between potential release sites at TA-54 and supply well PM-2 and gathering information about the extent of the capture zone at PM-2.

Table 7.1-1
Well Screen Information, Characterization Well R-20

Screen	Planned Depth (ft)	Actual Depth (ft)	Geologic/Hydrologic Setting
1	904.6–912.3	904.6–912.2	Near top of regional aquifer in cinder beds of the Cerros del Rio lavas
2	1147.2–1154.3	1147.1–1154.7	Within regional aquifer in the pumiceous Puye fanglomerate
3	1320.2–1336.9	1328.8–1336.5	Within regional aquifer in the Santa Fe Group sediments

Screen 1 was located near the top of the regional zone of saturation and is the shallow measurement point for vertical hydraulic gradients. This location was fixed relative to the water level of 873 ft bgs measured on August 27, 2002, with the top of the sand pack placed 20 ft below measured water level so the screen would be completely submerged for proper well development. Screen 1 also can be used to monitor groundwater quality near the top of the regional zone of saturation.

Screen 2 was located approximately halfway between screens 1 and 3 for vertical gradient information. Schlumberger geophysical logs were used to select a typical porosity/permeability zone for screen placement. Screen 2 also provides an opportunity to determine if water chemistry in this area is vertically stratified.

Screen 3 was located as deep as possible in the completed borehole for vertical gradient information. Schlumberger geophysical logs were used to select a relatively high-porosity/high-permeability zone for the screen so that the upper end of the permeability distributions could be targeted for straddle-packer/injection tests in the completed well. These deposits may represent a fast pathway in the regional system, and this screen provides an opportunity to characterize the groundwater at this depth.

7.2 Well Construction

The casing and pipe-based screens for R-20 were manufactured using 4.5-in.-ID/5-in.-OD, type 304 stainless steel fabricated to American Society for Testing and Materials (ASTM) standard A554. External couplings were also type 304 stainless steel fabricated to ASTM standards A312 and A511, both of which exceed the tensile strength of the threaded casing ends. The pipe-based screens were modified by Weatherford Well Screens (Johnson Screens, Inc.) from 10-ft sections of blank well casing. Weatherford drilled a series of 0.5-in.-diameter holes with 168 holes/ft and then welding a stainless steel wire-wrap (with 0.010-in. spacing) over the perforated interval. The final OD of the screens was 5.56 in.

All stainless steel well components were cleaned at the well site using a steam cleaner and scrub brushes. All annular materials were placed in the borehole/well casing annulus through a tremie pipe. Well construction activities were completed from September 8 to 15, 2002 (Figure 3.0-2).

7.2.1 Well Installation

Stewart Brothers installed the R-20 well casing and screen from September 8 to September 9, 2002. Well installation consisted of joints of stainless steel well casing and screen sections by means of threaded couplings. The bottom of the well was set at 1353.3 ft bgs. Stainless steel centralizers were installed above and below each screen and in several locations above the zone of regional saturation to centralize the well during annular fill placement operations. Figure 7.2-1 shows the as-built well casing configuration and indicates the depths of the various well components from ground surface.

7.2.2 Annular Fill Placement

From September 9 through 15, 2002, Stewart Brothers completed annular fill placement. A steel tremie pipe was used to deliver the annular materials to the specified depths (Figure 7.2-1). The bottom of the borehole was measured at 1362.5 ft bgs prior to material placement. Filter packs across screened intervals consisted of silica sand materials mixed with municipal water and placed in the annulus. Bentonite was placed between screened intervals to seal off the annular space and isolate the water-bearing zones. Bentonite was placed using EZ-Mud® polymer mixed with municipal water. Portland® cement (mixed at a ratio of 5 gal. of water to each bag of cement) was used to provide foundations for the annular fill above the regional aquifer and for wellhead protection in the annular space around the upper 75 ft of the borehole. Approximately 41,400 gal. of municipal water were used during placement of annular fill material.

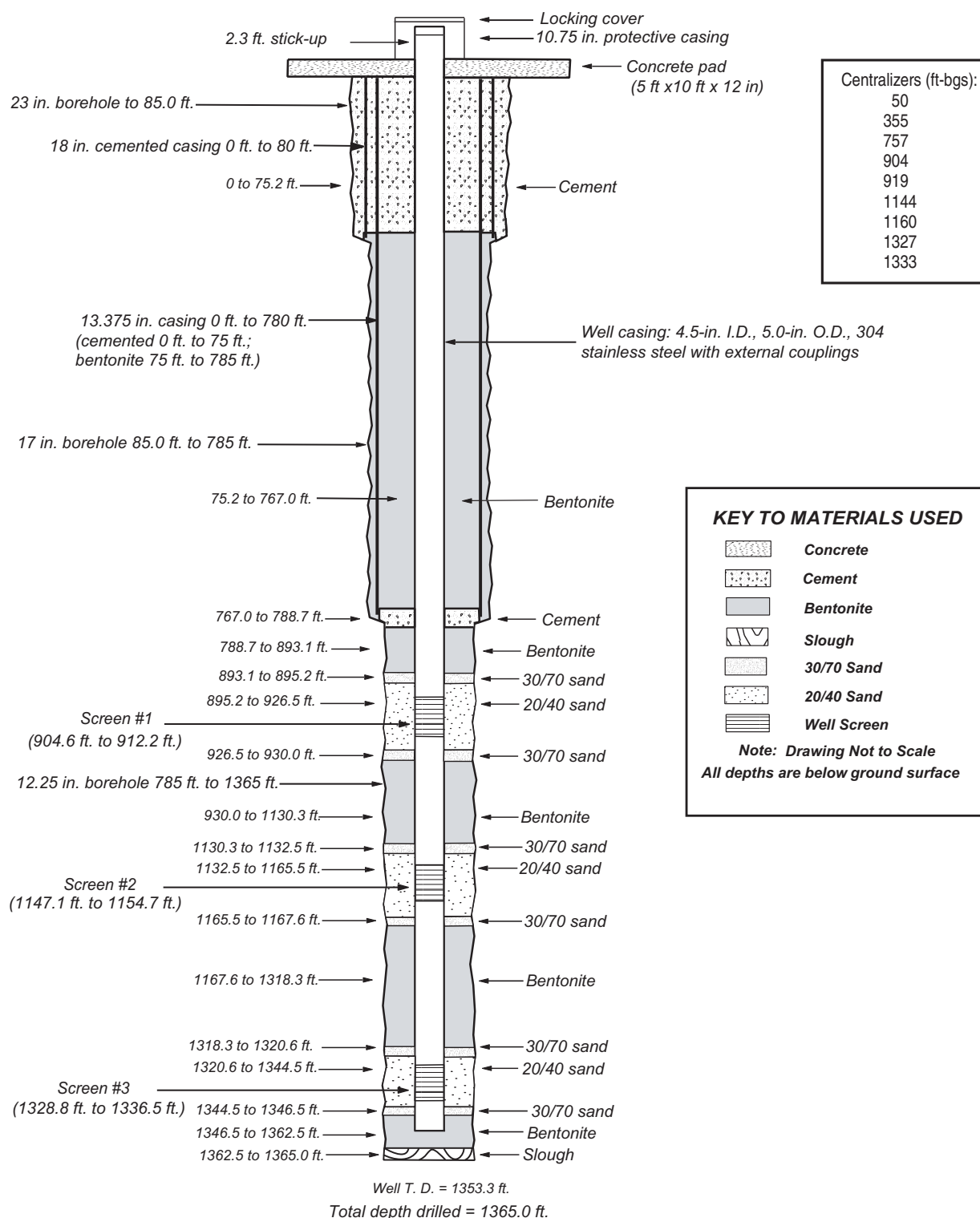
Table 7.2-1 summarizes the annular fill materials installed. The final configuration of annular materials is illustrated in Figure 7.2-1.

8.0 WELL DEVELOPMENT AND HYDROLOGIC TESTING

Well development and hydrologic testing activities at R-20 were conducted from September 15 to December 22, 2002 (Figure 3.0-2). Well-development procedures included wire-brushing, surging/bailing and chemically treating the well screens, and pumping. Development activities were followed by hydrologic tests conducted at all three well screens.

8.1 Well Development

Well development at R-20 was performed using a variety of methods. The initial stage consisted of wire-brushing the well interior, swabbing and surging the screened intervals to draw fine sediment from the constructed filter packs, and bailing to remove solid materials from the well. Chemical treatment procedures were applied to individual well screens to break up particulate matter and disperse borehole-wall filter cake that resulted from adding fluids during conventional mud-rotary drilling. The well then was pumped to remove remaining fines from the filter pack and adjacent formation.



- Note:
1. Each screen interval lists the footage of the pipe perforations, not the top and bottom of screen joints.
 2. The interval of slough consists of sands and gravel provisionally attributed to the Santa Fe Group.
 3. Westbay multiport sampling system (MP-55) casing not shown.
 4. Pipe-based screen: 4.5-in. I.D., 5.563-in. O.D., 304 stainless steel with s.s. wire wrap; 0.010-in. slot.
 5. Well sump interval: 1336.5 to 1353.3 ft.

Figure 7.2-1. As-built configuration diagram, characterization well R-20

Table 7.2-1
Annular Fill Materials, Characterization Well R-20

Material	Use/Function	Amount	Unit*
20/40 sand (medium-grained)	To pack screen intervals	115	bag
30/70 sand (fine-grained)	To separate filter packs from bentonite seals	27	bag
Benseal® (bentonite)	Granular (8-mesh) bentonite used for seals	5.5	bag
QUICK-GROUT®	High-solids bentonite grout used for seals	125	bag
Pelplug® bentonite (0.25-in. by 0.375-in., refined elliptical pellets)	To provide borehole annular seal below the water table	354	bucket
Portland® cement (mixed with municipal water at a ratio of 5 gal. water to 1 bag)	To provide annular support and surface seal on the upper portion of the borehole	48	bag

*Sand bag = 45 lb ea, bentonite bag/bucket = 50 lb ea, cement bag = 94 lb ea.

Criteria for well development were based on selected field water-quality parameters (turbidity, specific conductance, pH, and temperature). To monitor progress during development, samples of groundwater were withdrawn periodically and parameter measurements were made and recorded. One objective of well development was to remove suspended sediment from the water until turbidity stabilized to a value less than 5 nephelometric turbidity units (NTUs) for three consecutive samples. Similarly, other measured parameters needed to stabilize before the well could be declared successfully developed. The well was declared sufficiently developed when the above criteria were met or the measurements could not be improved. Table 8.1-1 presents pumping and water-quality parameter data recorded at the beginning and end of each well-development procedure.

Preliminary bailing using a 9-gal. steel bailer was performed from the R-20 well sump and screens 1, 2, and 3 between September 15 and 23, 2002. At that time, water produced from the well amounted to 6065 gal. To remove any materials that may have been introduced to the well interior during construction, the casing and screens were cleaned with a wire-brush system. Surging techniques were employed across all three screens using a surge block with an attached weight for rapid upward-downward strokes. The well screens were repeatedly surged, followed by periods of bailing. Surging/bailing activities were suspended on September 23, 2002.

On October 20, 2002, a dispersant solution containing 2.5 gal. of AQUA-CLEAR™-PFD (phosphate-free dispersant) in 950 gal. of municipal water was prepared and pumped into the well. Surging/bailing then was conducted across screens 1, 2, and 3. On October 23, 2002, an acidic solution containing 270 lb of AQUA-CLEAR™-MGA (modified granular acid) and 27 gal. of AQUA-CLEAR™-AE (acid enhancer) was mixed with 900 gal. of municipal water. Next, each of the three screened intervals was injected with approximately 300. gal of the mixture. Surging and bailing then resumed at each screen.

Development pumping began on October 25, 2002, and proceeded through November 1, 2002. Pumping initially was conducted at all screens without using inflatable packers. A 10-horsepower (hp) submersible pump then was lowered to the bottom of screen 3 and subsequently raised between screens 1 and 2. On/off cyclic pumping was conducted with approximately 30-min periods of nonpumping to allow water levels in the well to recover. Field parameters were measured hourly from collected water samples. A total of 61,760 gal. were pumped from the well during this phase of development.

Table 8.1-1
Development of Characterization Well R-20

Method	Water Produced (gal.)	Range of Parameters ^a			
		pH	Temperature (°C)	Specific Conductance (μS/cm) ^b	Turbidity (NTU)
Preliminary bailing/wire-brushing/surging	6,065	8.1–8.0	22.6–22.1	1481–259	>1000–226
Chemical treatment (add 950 gal. AQ-PFD)	+950	—	—	—	—
Surge/bail	850	9.1–9	19.5–23.3	1410–753	923→1000
Chemical treatment (add 900 gal. AQ-AE and AQ-MGA)	+900	—	—	—	—
Surge/bail	400	3–6	22.1	309	91.8
Pump	61,760	3.8–7.1	20.8–22.3	2318–104	23.1–6
Wire brush/bail	650	6.8–7	19.1–21	294–130	>1000→1000
Pump	1990	7–7	21–19.8	167–133	129–38.9
Pumping screen 3 w/packers	3850	6.7–6.6	23.2–24.1	121–106	57.4–4.7
Pumping at screen 2 w/packers	5255	7–7	22.1–21.8	107–128	112–2.8
Pumping at screen 3 w/packers	7925	6.8–6.7	22.6–20	114–108	185.6–4.2
Pumping at screen 1 w/packers	113	7.3	23.4	132	227
TOTAL	87,008				

^a Parameters presented as value at beginning followed by value at end of development method.

^b Specific conductance reported in microsiemens per centimeter (μS/cm).

On November 19, 2002, WGII conducted a video survey of the well. The survey found that sections of the well casing and screens 2 and 3 required additional wire-brush procedures. From November 21 to November 22, 2002, mechanical cleaning was followed by bailing and surging operations. Approximately 650 gal. of water were purged during these operations.

Development pumping using inflatable packers then was performed at each of the three screens. Packers were positioned above and below each screen to isolate the water-bearing zone, and pumping procedures, as described above, were applied to all three screens between December 4 and December 6, 2002. As indicated in Table 8.1-1, turbidity measurements from screens 3 and 2 were within acceptable ranges at the end of the pumping periods for both screens. Pumping procedures were also applied to screen 1. After withdrawing approximately 100 gal. from the well by pumping at this screen, the water level dropped below the pump intake. A total of 19,133 gal. were purged during this pumping phase. Groundwater samples were collected from screens 2 and 3 at the end of screen development.

A total of 87,008 gal. of water were withdrawn during all development activities conducted at R-20.

8.2 Hydrologic Testing

On December 10, 11, and 12, 2002, the Laboratory conducted straddle-packer/injection tests of saturated materials behind screens 1, 2, and 3 in well R-20. An injection assembly, consisting of two inflatable packers separated by a perforated pipe, was positioned around each screen. For a given screen, the

water-level response to injecting municipal water at different rates for different periods of time was monitored with a pressure transducer. Specifically, three tests were conducted at all three screens. A total of 1010 gal. of water was injected during these tests. Following the testing, approximately 8840 gal. of water were purged from the well. This amount represents more than five times the volume of water introduced during the tests. Results of these tests, as well as details of their design, implementation, and analysis, will be presented in a separate Laboratory report.

8.3 Installation of Westbay™ Monitoring System

A Westbay™ sampling system was installed inside the stainless steel well casing after development and testing procedures in well R-20 were completed. The base of the multiport casing was set at 1352.1 ft bgs. The system was set in place using a series of packers inflated with de-ionized water and positioned to target each well screen with a set of valve ports. The R-20 system contains eight ports used to monitor and test ten packers. Two measurement ports with a pumping port allow access to each screen. Quarterly sampling of Westbay™-equipped wells is accomplished using a Laboratory-owned sampling trailer equipped with the MOSDAX® sampling system (controller, sampler probe, and sample bottle train) and a motorized winch and boom system. The Westbay™ summary MP casing log provides details of the installed system (Appendix F, on a CD on the inside back cover of this report).

9.0 WELLHEAD COMPLETION AND SITE RESTORATION

After completion of the pump installation, finish work commenced on the wellhead area. Well components were surveyed, and the site underwent final cleanup and restoration.

9.1 Wellhead Completion

Surface completion for well R-20 involved installing a reinforced (3000 lb/square inch [psi]) concrete pad, 5-ft wide by 10-ft long by 6-in. thick, around the well casing to ensure long-term structural integrity of the well (Figure 9.1-1). The concrete pad was poured on November 13, 2002, and a brass survey cap was installed in the northwest corner of the concrete pad. The pad was designed to be slightly elevated, with base-course gravel graded around the pad to allow drainage. A 10-in. steel casing with locking lid protects the well riser. A 4-in.-diameter steel bollard was placed next to each of the four sides of the pad. One bollard can be removed to allow access to the well for sampling and maintenance.

9.2 Geodetic Survey

Southwest Mountain Surveys, Inc. (NMPLS #6998), conducted a geodetic survey of well R-20 on December 19, 2002, using a global positioning satellite (GPS) system. The GPS system utilized National Geodetic Vertical Datum of 99/96 for vertical computations and the datum for the horizontal control network is North American Datum 1983 (NAD 83). The survey located the brass monument in the northwest corner of the concrete pad and measured location and elevation at the top of the steel protective casing, the top of the Westbay™ cap, and the top of the Westbay™ plate (Table 9.2-1). The coordinates shown are in New Mexico State Plane coordinates, Central Zone (NAD 83) expressed in feet. To be consistent with current Laboratory standards, elevations are expressed in feet above mean sea level and referenced to the National Geodetic Vertical Datum of 1929 (NGVD29).

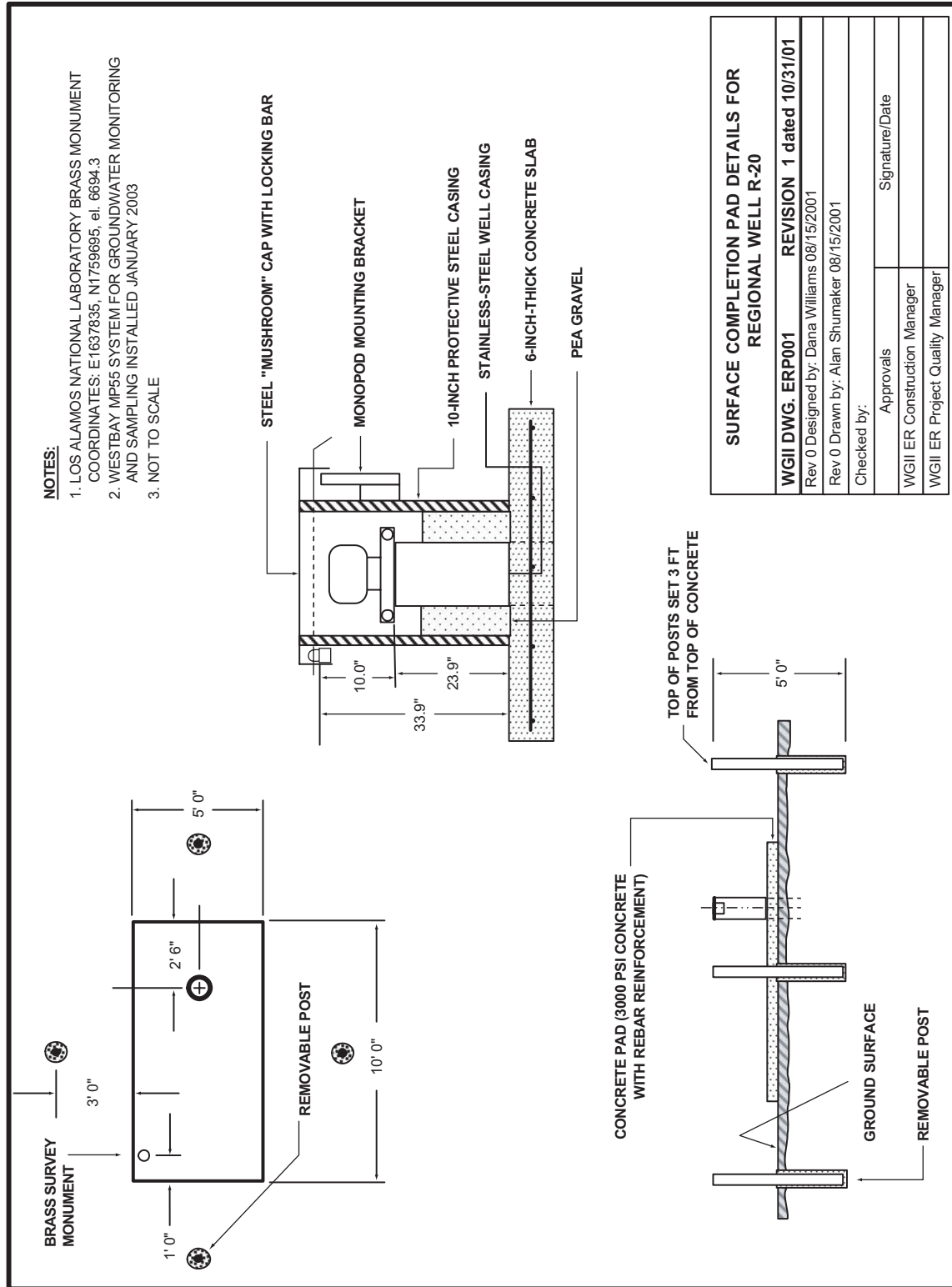


Figure 9.1-1. Surface completion configuration diagram, characterization well R-20

Table 9.2-1
Geodetic Data, Characterization Well R-20

Description	East	North	Elevation
Brass monument in R-20 pad	1637835.40	1759694.51	6694.35
Top of Westbay™ landing plate	1637839.83	1759689.78	6696.68
Top of Westbay™ casing	1637839.92	1759689.73	6697.14
Top of steel protective well casing	1637839.66	1759689.89	6697.68

9.3 Site Restoration

Drilling site restoration activities at R-20 were conducted by K. R. Swerdfeger Construction, Inc., from February 24 to March 6, 2003 (Figure 3.0-2). Prior to and along with restoration, waste-management activities were also performed. Waste materials were removed from the site according to the WCSF. Drilling activity media included drilling fluids, cuttings, and development water. These were sampled for contaminant analysis (Appendix G). After the Laboratory and NMED reviewed the test data, the waste was approved for land application. The drill cuttings were used to help backfill the cuttings-containment area and the drilling fluids and development water were applied around the site with a 3-in.-pipe irrigation system as specified in the Notice of Intent. The waste streams from minor spill clean up included petroleum-contaminated soils and absorbent materials used during clean up. After the Laboratory approved the waste profile forms submitted by waste-management personnel the waste streams were disposed of as New Mexico Special Waste. Before the site was graded, the cuttings-containment area was excavated and the plastic lining was removed. The containment basin area then was backfilled with dirt that had been bermed during pad construction and regraded. Base-course gravel was also regraded and compacted across the site to form a smaller pad. The site was re-seeded with a blend of native grasses mixed with fertilizer to facilitate regrowth of ground cover.

10.0 DEVIATIONS FROM THE R-20 SAP

There were no significant deviations between the actual characterization activities versus planned activities described in the SAP.

11.0 ACKNOWLEDGEMENTS

Dynatec Drilling Company provided rotary drilling services.

Tetra-Tech EM, Inc.; D. B. Stephens and Associates, Inc.; and S. M. Stoller provided support for well-site geology, sample collection, and hydrologic testing.

Southwest Mountain Surveys, Inc. (NMPLS #6998), provided the final geodetic survey of finished well components.

D. Thompson and C. Schultz of PMC Technologies (Exton, Pennsylvania) and P. Schuh, E. Tow, and R. Lawrence of Tetra-Tech EM, Inc. (Albuquerque, New Mexico), contributed to the preparation of this report.

R. Bohn and E. Louderbough of Los Alamos National Laboratory reviewed this report for classification and legal purposes, respectively.

D. Broxton, P. Longmire, S. Pearson, W. Stone, and D. Vaniman of Los Alamos National Laboratory prepared this report.

Schlumberger Integrated Water Solutions provided processing and interpretation of borehole geophysical data.

12.0 REFERENCES

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Appendix A

Activities Planned for R-20 Compared with Work Performed

Activity	“Hydrogeologic Workplan” (LANL 1998, 59599)	“Pajarito Canyon Workplan” (LANL 1998, 58820)	R-20 Sampling and Analysis Plan	R-20 Actual Work
Planned Depth	100 to 500 ft into the regional aquifer	Planned depth of 950 ft below ground surface (bgs)	Estimated depth of 1354 ft bgs	Total drill depth 1365 ft bgs
Drilling Method	Methods may include, but are not limited to, hollow-stem auger (HSA), air-rotary/Odex/Stratex, air-rotary/Barber rig, and mud-rotary drilling	Drilling methods not specified	Stiff foam air rotary, air-rotary, mud-rotary flooded-reverse circulation, and fluid-assist air-rotary with casing-advance	Conventional mud rotary, fluid-assisted air rotary with casing-advance, and air-rotary core with wireline retrieval
Amount of Core	10% of the borehole	May be continuously cored to 950 ft bgs	Continuous core from surface to estimated depth of 444 ft bgs (50 ft into Cerros del Rio), but no deeper than 450 ft bgs	Continuous core from surface to 436 ft bgs (44 ft into Cerros del Rio lavas)
Lithologic Log	Log to be prepared from core, cuttings, and drilling performance data	Log preparation not specified	Log to be prepared from core, cuttings, geophysical logs and drilling performance data	Log prepared from core, cuttings, geophysical logs, and drilling performance data
Number of Water Samples Collected for Contaminant Analysis	A water sample may be collected from each saturated zone, five zones assumed. The number of sampling events after well completion is not specified.	A water sample may be collected from each saturated zone, four zones assumed (3 intermediate perched zones and the regional aquifer). After the well is completed, groundwater from two depths will be sampled and analyzed, continuing on a semi-annual basis for two years.	If perched water is encountered, within the unsaturated zone, one groundwater-screening sample will be collected within up to three perched zones. Groundwater-screening samples will be collected within the regional aquifer at the regional water table and at the TD of the borehole.	One alluvial water sample collected at 17.5 ft. Two groundwater samples collected from screens 2 and 3.

Activity	"Hydrogeologic Workplan" (LANL 1998, 59599)	"Pajarito Canyon Workplan" (LANL 1998, 58820)	R-20 Sampling and Analysis Plan	R-20 Actual Work
Water Sample Analysis	Initial sampling: radiochemistry I, II, and III, tritium, general inorganics, stable isotopes, volatile organic compounds (VOC), and metals. Saturated zones: radionuclides (tritium, ⁹⁰ Sr, ¹³⁷ Cs, ²⁴¹ Am, plutonium isotopes, uranium isotopes, gamma spectrometry and gross alpha, beta, and gamma), stable isotopes (hydrogen, oxygen, and in special cases nitrogen), major ions (cations and anions), trace metals, and trace elements.	Anions, trace elements, VOCs, SVOCs, HE, dissolved organic carbon, total suspended solids, neutral species, hardness, cyanide, stable and radiogenic isotopes (^{13,14} carbon, ³⁶ chloride, D/H, ¹⁸ O/ ¹⁶ O), ²⁴¹ Am, ¹³⁷ Cs, ²³⁸ Pu, ^{239,240} Pu, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁰ Sr, gamma spec, gross-alpha, -beta, -gamma, and tritium (low-detection limit)	Metals (dissolved), anions (dissolved), VOCs, ⁹⁹ Tc, gamma spec, ²⁴¹ Am, ¹³⁷ Cs, ²³⁸ Pu, ^{239,240} Pu, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁰ Sr, stable isotopes (¹⁸ O/ ¹⁶ O, D/H, ¹⁵ N/ ¹⁴ N), tritium, tritium (low-level or direct counting), RV gross-alpha, beta, gamma	Following well completion and development, groundwater samples (from screens 2 and 3 were analyzed for inorganic and organic chemicals, tritium, radionuclides, stable isotopes, and anions.
Water Sample Field Measurements	Alkalinity, dissolved oxygen, pH, specific conductance, temperature, turbidity	Alkalinity, dissolved oxygen, pH, specific conductance, temperature, turbidity	Alkalinity, pH, specific conductance, temperature, turbidity	pH, specific conductance, temperature, turbidity
Number of Core/Cuttings Samples Collected for Contaminant Analysis	Twenty samples of core or cuttings to be analyzed for potential contaminant identification in each borehole.	Number of core/cuttings samples to be collected not specified	Core samples to be collected at target depths of 10, 20, 30, 40, 50, 75, 100, 150, 200, 300, and 400 ft	13 core/cuttings samples submitted for analysis
Core/Cuttings Sample Analytes	Upper-most core or cuttings sample to be analyzed for a full range of compounds; deeper samples to be analyzed for the presence of radiochemistry I, II, and III analytes, tritium (low- and high-detection levels), and metals. Four samples to be analyzed for VOCs.	Upper-most core or cuttings sample to be analyzed for a full range of compounds; deeper samples to be analyzed for major and minor anions, trace elements, and tritium (low- and high-detection limit), as well as other contaminants of potential concerns (COPCs) appropriate for that location. In addition, selected samples will be analyzed for VOCs and semivolatile organic compounds (SVOCs).	Analytical suite for core/cuttings samples includes anions, stable isotopes, tritium profiles, ²⁴¹ Am, ²³⁸ Pu, ^{239,240} Pu, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁰ Sr, gamma spectroscopy, radiological screening (gross alpha, beta, and gamma), radionuclides, and metals.	Samples submitted for anions and radionuclides.

Activity	"Hydrogeologic Workplan" (LANL 1998, 59599)	"Pajarito Canyon Workplan" (LANL 1998, 58820)	R-20 Sampling and Analysis Plan	R-20 Actual Work
Laboratory Hydraulic-Property Tests	Physical properties analyses will be conducted on 5 core samples and will typically include moisture content, porosity, particle density, bulk density, saturated hydraulic conductivity, and water retention characteristics.	Retrieved core and cuttings samples will be analyzed for moisture content, at 10-ft intervals, except where saturation is encountered. Hydraulic properties analyses will be conducted on core samples based on geologic and hydrologic conditions encountered.	Core samples for anion profiles will be measured for moisture content.	13 samples submitted for moisture analysis. Other properties may be inferred from geophysics.
Geophysics	In general, open-hole geophysics includes caliper, electromagnetic induction, natural gamma, magnetic susceptibility, borehole color videotape (axial and side scan), fluid temperature (saturated), fluid resistivity (saturated), Single-point resistivity (saturated), and spontaneous potential (saturated). In general, cased-hole geophysics includes: gamma-gamma density, natural gamma, and thermal neutron.	Portions of the borehole may be logged with open-hole tools if borehole stability is such that the borehole can be advanced without casing. Cased-hole wire line logging will be conducted in the cased-off borehole and well.	The number and types of logs will vary as a function of borehole condition and the presence or absence of drill or well casing. In general, open-hole geophysics includes caliper, array induction, triple lithodensity, combinable magnetic resonance, natural gamma, natural gamma ray spectrometry, epithermal compensated neutron, Mechanical sidewall coring tool, fullbore formation microimager, and borehole color videotape (axial and side scan). In general, cased-hole geophysics includes: triple lithodensity, natural gamma ray spectrometry, natural gamma, and epithermal compensated neutron.	LANL tools: natural gamma, induction; borehole video Schlumberger geophysics: NGS, AITH™, TLD™, ECS™, CMR™, FMI™, DSLT
Water-Level Measurements	Procedures and methods not specified	Not specified	Water levels will be determined for each saturated zone by water-level meter or by pressure transducer.	Water-level meter determined water levels for the regional water table.

Activity	"Hydrogeologic Workplan" (LANL 1998, 59599)	"Pajarito Canyon Workplan" (LANL 1998, 58820)	R-20 Sampling and Analysis Plan	R-20 Actual Work
Field Hydraulic-Property Tests	Tests to be conducted not specified	Not specified	Straddle-packer/injection tests will be performed in all screens completed below the regional water table.	Constant-rate injection tests were conducted on screens 1, 2, and 3.
Surface Casing	Approximately 20-in. outer diameter (OD), extends from land surface to 10-ft depth in underlying competent layer and grouted in place.	Not specified	Install 18-in. or 20-in.-OD steel casing to approximately 60 ft.	18.375-in.-OD steel casing set at 80 ft, cemented in place
Conductor Casing	Unless other technical methods are applied, a temporary steel casing, up to 14-in.-OD, will be advanced to total depth of borehole.	Not specified	Install 11.75-in.-OD drill casing from 0 to ~700 to 800 ft bgs, or approximately 100 ft above anticipated regional water level, or set thin-wall casing over problem zone(s) and seal off casing using materials to meet regulatory requirements.	13.375-in.-OD-drill casing from 0 to 780 ft bgs
Minimum Well Casing Size	6 5/8-in. OD	Not specified	5-in. OD	5-in.-OD by 4.5-in.-inner diameter (ID) stainless steel casing w/ external couplings
Well Screen	Machine-slotted (0.01-in.), stainless steel screens with flush-jointed threads; number and length of screens to be determined on a site-specific basis and proposed to NMED.	Not specified	Well screen shall be constructed with multiple sections of 5.5-in. OD stainless steel pipe with wire wrap (0.010-in. slot opening).	Screened intervals constructed of 5.56-in.-OD (4.5-in.-ID) pipe based, stainless steel, wire-wrapped, 0.010-in. slotted screen opening).

Activity	"Hydrogeologic Workplan" (LANL 1998, 59599)	"Pajarito Canyon Workplan" (LANL 1998, 58820)	R-20 Sampling and Analysis Plan	R-20 Actual Work
Filter Material	>90% silica sand, properly sized for the 0.010-in. slot size of the well screen; extends 2 ft above and below the well screen	Not specified	Filter pack shall extend at least 5 ft and no more than 10 ft above and below each well screen. No differentiation made between primary and secondary filter packs.	<p>Primary filter pack consisted of 20/40 silica sand placed 8 ft below and 8.2 ft above screen 3. Secondary filter pack consisted of 30/70 silica sand placed in a layer 2-ft-thick below and 2.3-ft-thick above.</p> <p>Primary filter pack consisted of 20/40 silica sand placed 10.8 ft below and 14.6 ft above screen 2. Secondary filter pack consisted of 30/70 silica placed in a layer 2.1-ft-thick below and 2.2-ft-thick above.</p> <p>Primary filter pack consisted of 20/40 silica sand placed 14.3 ft below and 9.4 ft above screen 1. Secondary filter pack of 30/70 silica sand placed in a layer 3.5-ft-thick below and 2.1-ft-thick above.</p>
Annular Fill Material (exclusive of filter materials)	Uncontaminated drill cuttings below sump and bentonite above sump	Not specified	Bentonite and cement in borehole or well annulus.	<p>Slough in bottom of borehole and bentonite seals below and above screens 3, 2, and 1 filter packs</p> <p>Cement plug from 767 to 788.7 ft bgs</p> <p>Cement-bentonite grout from surface to 75.2 ft bgs</p>
Sump	Stainless steel casing with an end cap	Not specified	Not specified	5-in. diameter stainless steel casing, 16.8-ft-long, with an end cap.
Bottom Seal	Bentonite	Not specified	Bentonite	Bentonite

Appendix B

*Drill-Additive Product Specifications
(CD attached to inside back cover)*

Appendix C

Lithology Log

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Qal, Alluvium	No cuttings recovered in this interval.	0–25	6694.3–6669.3
	Volcaniclastic sediments, light brown (5YR 6/4), lithic-rich. +10F (i.e., plus No. 10 size sieved sample fraction): 97% broken light gray porphyritic dacite lithic fragments, limonite common on fractured surfaces; 3% quartz and sanidine crystals (up to 2.0 mm). +35F (i.e., plus No. 35 size sieved sample fraction): 70–80% dacite lithic fragments; 20–30% quartz and sanidine crystals.	25–35	6669.3–6659.3
	Volcaniclastic sediments, light olive-gray (5Y 6/1), lithic-rich. +10F: 98% broken light gray porphyritic dacite lithic fragments, most have iron oxide coating on fractured surfaces, most have bleached coloration; 2% quartz and sanidine crystals. +35F: 80% dacite lithic fragments; 20% quartz and sanidine crystals; no pumices.	35–45	6659.3–6649.3
	Volcaniclastic sediments, light olive-gray (5Y 6/1), lithic-rich. +10F: 99% broken light gray porphyritic dacite lithic fragments (most have Fe-oxide coatings on fractured surfaces and bleached coloration), minor rhyodacite, rare quartzite; 1–5% quartz and sanidine crystals; no pumices. +35F: 90% dacite lithic fragments; 10% quartz and sanidine crystals; no pumices.	45–55	6649.3–6639.3
	Volcaniclastic sediments, light olive-gray (5Y 6/1), lithic-rich. +10F: 97–98% light gray porphyritic lithic fragments that are broken to subangular, most have bleached coloration; minor latite and rhyodacite; 2–3% quartz and sanidine crystals; no pumices. +35F: 95% volcanic lithic fragments; 5% quartz and sanidine crystals; no pumices.	55–65	6639.3–6629.3
	Volcaniclastic sediments, light brown (5YR 6/4), lithic-rich. +10F: 95–97% volcanic lithic fragments that are broken to subangular chips (less than 3 mm), gray porphyritic dacite much more common than rhyolite, minor indurated tuffaceous sediments; 2–5% quartz and sanidine crystals; no pumices. +35F: 65% volcanic lithic fragments; 35% quartz and sanidine crystals; no pumices. Note: Qal/Qbt contact is estimated at 68 ft bgs	65–75	6629.3–6619.3
Qbt, Tshirege Member, Bandelier Tuff (Undivided)	Rhyolite tuff, light brownish-gray (5YR 6/1), lithic-rich. +10F: 95–97% volcanic lithic fragments that are broken to subangular chips, gray to whitish (bleached) dacite more common than rhyolite, minor tuffaceous sandstone; 3–5% quartz and sanidine crystals; pumices absent. +35F: 35% volcanic lithic fragments; 65% quartz and sanidine crystals; pumices absent.	75–85	6619.3–6609.3
	No cuttings recovered in this interval.	85–100	6609.3–6594.3
	Rhyolite tuff, pinkish-gray (5YR 8/1), pumice-rich, clayey or vitric ash matrix. +10F: 99% broken chips of whitish-pumices (up to 1.7 cm) with minor alteration to clay; 1% dacite lithic fragments. +35F: 38% pumices; 60% phenocrysts; 2% lithic fragments.	100–105	6594.3–6589.3
	Rhyolite tuff, pinkish-gray (5YR 8/1), pumice and lithic fragment-rich. +10F: 60% pumice fragments (up to 1.0 cm), with minor alteration to clay; 40% volcanic lithic fragments, mostly gray and pink dacite, rare basalt fragments.	105–110	6589.3–6584.3

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Qbt, Tshirege Member, Bandelier Tuff (Undivided)	Rhyolite tuff, pinkish-gray (5YR 8/1), pumice and lithic fragment-rich, clayey ash matrix. +10F: 65% coarse pumice fragments (up to 1.2 cm), slight clay alteration; 30–35% volcanic lithic fragments, mostly subangular gray and pink dacite (up to 1.0 cm). +40F: 15–25% pumice; 60–70% phenocrysts; 3–5% lithic fragments.	110–120	6584.3–6574.3
	Rhyolite tuff, pinkish-gray (5YR 8/1), pumice-rich, clayey ash matrix. +10F: 75% pumice fragments (up to 1.0 cm) unaltered to clay alteration evident; 10% phenocrysts; 15% lithic fragments, mostly subangular gray dacite (up to 0.5 cm). +40F: 30% pumice; 65% phenocrysts; 5% lithic fragments.	120–125	6574.3–6569.3
	Rhyolite tuff, yellowish-gray (5Y 8/1), pumice-rich, clayey ash matrix. +10F: 97–99% pumice fragments (up to 1.0 cm), earthy to frothy vitric texture; no phenocrysts evident; 1–3% lithic fragments. +40F: 10–25% pumice; 75–85% phenocrysts; 2–3% lithic fragments.	125–135	6569.3–6559.3
Qbt	Rhyolite tuff, yellowish-gray (5Y 8/1), pumice-rich, clayey ash matrix. +10F: 80–90% pumice fragments (up to 1.5 cm), earthy to vitric texture; no phenocrysts evident; 10–20% lithic fragments with 10–12% clay-cemented crystal and pumice-rich sandstone. +40F: 35% pumice; 25% phenocrysts; 40% lithic fragments.	135–145	6559.3–6549.3
	Rhyolite tuff, yellowish-gray (5Y 8/1), pumice-rich, clayey ash matrix. +10F: 65–75% pumice fragments (up to 1.0 cm), white vitric luster, minor clay alteration; no phenocrysts evident; 25–35% lithic fragments (up to 0.7 cm), dacite prominent, rhyodacite common, minor basalt. +35F: 50–60% pumice; 20–25% phenocrysts; 15–20% lithic fragments.	145–160	6549.3–6534.3
	Rhyolite tuff, yellowish-gray (5Y 8/1), pumice-rich, moderate clay in the ash matrix. +10F: 75% pumice fragments (up to 1.0 cm), fresh vitric luster, minor clay alteration; no phenocrysts evident; 25% lithic fragments, mostly subangular dacite, rare quartzite. +35F: 15% pumice; 25% phenocrysts; 60% lithic fragments.	160–165	6534.3–6529.3
Qct, Cerro Toledo Interval	Tephra/tuffaceous sediments, light olive-gray (5Y 6/1), lithic-rich, moderate clay in the ash matrix. +10F: 3–5% pumice; no phenocrysts evident; 95–97% volcanic lithic fragments, mixture of subangular to subrounded dacite and rhyodacite. Note: Qbt/Qct contact estimated at 166 ft bgs.	165–175	6529.3–6519.3
	Tephra/tuffaceous sediments, light brownish-gray (5YR 6/1), lithic-rich. +10F: 100% volcanic lithic fragments (clasts up to 1.5 cm), mixture of subangular to subrounded dacite, silicified dacite, and flow-banded rhyodacite. +35F: 10–20% pumice; 5–15% quartz and sanidine crystals; 75–85% volcanic lithic fragments. Note: Qct/ Qbo contact estimated at 183 ft bgs.	175–185	6519.3–6509.3

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Qbo, Otowi Member, Bandelier Tuff	Rhyolite tuff, light brownish-gray (5YR 6/1), lithic-rich. +10F: 97% volcanic lithic fragments, gray and pink broken subangular to subrounded chips (up to 2.0 cm) of porphyritic dacite, flow-banded rhyodacite, and hornblende latite(?); 3–5% pumice with slight clay alteration. +35F: 10–15% pumice; 25–50% quartz and sanidine phenocrysts; 30–40% volcanic lithic fragments.	185–195	6509.3–6499.3
	Rhyolite tuff, light brownish-gray (5YR 6/1), lithic-rich. +10F: 99% volcanic lithic fragments, broken to subrounded gray dacite and white latite; 1–2% limonite stained pumice fragments. +35F: 10–20% pumice; 50–70% quartz and sanidine phenocrysts; 40–50% lithic fragments.	195–210	6499.3–6484.3
	Rhyolite tuff, varicolored, very light gray (N7) to light pinkish-gray (5YR 6/1), lithic-rich, pumiceous. +10F: 65–70% volcanic lithic fragments, broken to subrounded pink and gray dacite and white flow-banded rhyodacite (up to 1.0 cm); 30–35% pumice fragments (up to 1.5 cm), white to orange, vitric with weak clay alteration; +35F: 30% pumice; 25% quartz and sanidine phenocrysts; 45% lithic fragments.	210–215	6484.3–6479.3
	Rhyolite tuff, light brownish-gray (5YR 6/1), lithic- and pumice-rich. +10F: 60–70% volcanic lithic fragments (up to 0.7 cm, broken to subrounded, pink and gray dacite and whitish flow-banded rhyodacite; 30–40% pumice fragments (up to 1.0 cm), white to pale yellowish-brown, vitric with weak clay alteration +35F: 2–8% pumice; 60–70% quartz and sanidine phenocrysts; 15–45% lithic fragments.	215–230	6479.3–6464.3
	Rhyolite tuff, light brownish-gray (5YR 6/1), lithic-rich. +10F: 100% volcanic lithic fragments (up to 0.7 cm), broken to subangular, mostly gray dacite with minor siliceous rhyodacite. +35F: 2% pumice; 78% quartz and sanidine phenocrysts; 20% lithic fragments.	230–235	6464.3–6459.3
Qbo	Rhyolite tuff, pinkish-gray (5YR 8/1), lithic-rich, pumiceous, pale tan clayey ash matrix. +10F: 70–90% volcanic lithic fragments (up to 0.8 cm), mostly pink and gray broken to subrounded dacite with minor silicic rhyodacite; 10–30% pumice fragments (up to 1.8 cm), white to orange, vitric, limonite-stained. +35F: 20–30% pumice; 40–60% quartz and sanidine phenocrysts; 20–30% lithic fragments.	235–245	6459.3–6449.3
	Rhyolite tuff, pinkish-gray (5YR 8/1), lithic-rich. +10F: 85–90% volcanic lithic fragments, mostly broken to subangular porphyritic dacite, locally bleached and/or altered; 7–15% pumice fragments, white, weak clay alteration. +35F: 20–25% white and yellow pumice; 50–60% quartz and sanidine phenocrysts; 15–20% lithic fragments.	245–255	6449.3–6439.3
	Rhyolite tuff, yellowish-gray (5Y 8/1), lithic and pumice-rich, clayey ash matrix. +10F: 40–50% volcanic lithic fragments, mostly subangular gray and bleached and/or altered dacite (up to 1.0 cm), trace of gray quartzite; 40–50% pumice (up to 1.5 cm), white to pale orange, vitric, some limonite staining. +35F: 25% pumice; 35% quartz and sanidine phenocrysts; 40% lithic fragments.	255–260	6439.3–6434.3

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Qbo	Rhyolite tuff, yellowish-gray (5Y 8/1), pumice-rich. +10F: 75% pumice, white to pale orangish tan, vitric, some clay alteration (up to 1.5 cm). 25% volcanic lithic fragments, mostly gray to bleached dacite. +35F: 30% pumice; 30% quartz and sanidine phenocrysts; 35% lithic fragments.	260–265	6434.3–6429.3
	No cuttings returned in this interval.	265–275	6429.3–6419.3
	Rhyolite tuff, yellowish-gray (5Y 8/1), lithic- and pumice-rich, some clay in ash matrix. +10F: 70–75% volcanic lithic fragments (up to 0.7 cm), mostly gray, pink, and white (bleached) dacite; 25–30% white pumice (up to 1.0 cm), unaltered to slight clay alteration. +35F: 40% pumice; 20% quartz and sanidine phenocrysts; 40% lithic fragments.	275–280	6419.3–6414.3
	Rhyolite tuff, varicolored, yellowish-gray (5Y 8/1) to medium gray (N5), lithic- and pumice-rich. Poor sample recovery. WR: 45–55% white pumice (up to 0.7 cm), unaltered to slight clay alteration; 40–50% volcanic lithic fragments (up to 0.7 cm), angular to subangular.	280–290	6414.3–6404.3
	Rhyolite tuff, varicolored, yellowish-gray (5Y 8/1) to medium gray (N5), lithic- and pumice-rich, clayey with clayey ash matrix and clay-coated chips. +10F: 40–60% white pumice, unaltered to clay altered and some pale orange limonite-stained pumices; 40–60% volcanic lithic fragments (up to 0.7 cm), gray to white (bleached) dacite. +35F: 25–35% pumice; 20–30% quartz and sanidine phenocrysts; 35–45% lithic fragments.	290–300	6404.3–6394.3
	Rhyolite tuff, light brownish-gray (5YR 6/1), lithic- and pumice-rich. Poor sample recovery. +10F: 65–70% volcanic lithic fragments dacite (up to 0.7 cm), angular to subangular gray and pink; 30–35% white pumice (up to 1.0 cm), vitric to clay altered.	300–305	6394.3–6389.3
	Rhyolite tuff, light brownish-gray (5YR 6/1), lithic- and pumice-rich, clayey ash matrix. +10F: 60–65% volcanic lithic fragments, gray and pink dacite; 35–40% white pumice (up to 1.0 cm), vitric to clay altered. +35F: 60% pumice; 15% quartz and sanidine phenocrysts; 25% lithic fragments.	305–310	6389.3–6384.3
	Rhyolite tuff, light brownish-gray (5YR 6/1), lithic- and pumice-rich, clayey ash matrix. +10F: 75% white pumice (up to 1.5 cm), clay altered; 25% volcanic lithic fragments, gray dacite and flow-banded rhyolite. +35F: 60% pumice; 15% quartz and sanidine phenocrysts; 25% lithic fragments.	310–315	6384.3–6379.3
	Rhyolite tuff, light brownish-gray (5YR 6/1), lithic- and pumice-rich, clayey ash matrix. +10F: 50–60% white pumice (up to 1.5 cm) vitric to slight clay alteration; 40–50% volcanic lithic fragments, angular to subangular, light to dark gray dacite. +40F: 25–45% pumice; 30–50% quartz and sanidine phenocrysts; 30–40% lithic fragments.	315–330	6379.3–6364.3
	Rhyolite tuff, light brownish-gray (5YR 6/1), pumice-rich, clayey ash matrix. +10F: 85–90% white pumice (up to 1.5 cm), vitric to slight clay alteration; 10–15% dacite lithic fragments. +40F: 40–50% pumice; 15–20% quartz and sanidine phenocrysts; 35–45% lithic fragments.	330–335	6364.3–6359.3

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Qbo	Rhyolite tuff, grayish-orange pink (5YR 7/2), pumice- and lithic-rich, 25–30% clay in the matrix. +10F: 50–70% white pumice (up to 1.0 cm), vitric to some clay alteration; 30–50% light and dark gray angular to subangular dacite lithic fragments. +40F: 35–40% pumice; 30–35% quartz and sanidine phenocrysts; 25–30% lithic fragments.	335–345	6359.3–6349.3
	Rhyolite tuff, grayish-orange pink (5YR 7/2), pumice- and lithic-rich, 30–40% clay matrix. +10F: 40–60% white pumice (up to 0.5 cm), vitric to slight clay alteration. +40F: 40–45% pumice; 25–30% quartz and sanidine phenocrysts; 25–30% lithic fragments.	345–360	6349.3–6334.3
	Rhyolite tuff, yellowish-gray (5Y 8/1), pumice- and lithic-rich, clayey matrix. +10F: 45–50% pumice (up to 0.5 cm), vitric to slight clay alteration; 5–10% quartz and sanidine phenocrysts; 40–45% volcanic lithic fragments, light and dark gray dacite, some hornblende latite. +35F: 50% pumice; 25% quartz and sanidine phenocrysts; 25% lithic fragments.	360–365	6334.3–6329.3
	Rhyolite tuff, yellowish-gray (5Y 8/1), 25–30% clay-rich matrix. +10F: 60–80% white pumice (up to 0.7 cm) vitric to moderate clay alteration; 20–40% volcanic lithic fragments, gray to pinkish dacite. +35F: 25–30% pumice; 40–50% quartz and sanidine phenocrysts; 20–25% lithic fragments. Note: Qbo/Qbog contact estimated at 374 ft bgs.	365–375	6329.3–6319.3
Qbog, Guaje Pumice Bed	Tephra deposit, yellowish-gray (5Y 8/1), pumice and lithic-rich, 25–30% clay-rich matrix. +10F: 55–65% white pumice (up to 1.0 cm), vitric to moderate clay alteration; 35–45% volcanic lithic fragments (up to 0.5 cm), pink and light gray dacite. +35F: 35% pumice; 40% quartz and sanidine crystals; 25% lithic fragments.	375–385	6319.3–6309.3
	Tephra deposit, yellowish gray (5Y 8/1), pumice and lithic-rich, 25–30% clay-rich matrix. +10F: 55–60% white pumice, (up to 1.0 cm), vitric to moderate argillic alteration; 40–45% volcanic lithic fragments (up to 0.5 cm), pink and gray dacite. +35F: 35% pumice; 30% quartz and sanidine crystals; 30% lithic fragments.	385–390	6309.3–6304.3
Tb4, Cerro del Rio basalt	Transitional Qbog/Tb 4 interval, light brownish-gray (5YR 6/1), mixed rhyolite and basalt chips, clayey matrix. +10F: 25–30% light pinkish tan very fine-grained indurated tuffaceous sandstone; 20–30% broken chips of black vesicular basalt vitrophyre with abundant limonitic clay rinds and coatings (palagonite?); 15–20% white pumice with slight clay alteration; 10–15% light gray subangular to subrounded dacite lithic fragments. Note: Qbog/Tb4 contact estimated at 392 ft bgs.	390–395	6304.3–6299.3
	Olivine basalt, medium dark gray (N4), porphyritic with microcrystalline groundmass, vesicular, light clay coating on chips. +10F: 3–5% brown olivine phenocrysts (up to 1.0 mm), oxidized and replaced by iddingsite; groundmass plagioclase slightly altered; tan clay coating on fractures and lining vesicles.	395–405	6299.3–6289.3

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tb4 Cerro del Rio Basalt	Olivine basalt, medium-dark gray (N4), slightly porphyritic with aphanitic groundmass, massive to slightly vesicular, clay coating on chips. +10F: 2–3% unaltered greenish olivine phenocrysts (up to 0.5 mm); groundmass partly altered.	405–415	6289.3–6279.3
	Olivine basalt, medium-dark gray (N4), slightly porphyritic with aphanitic groundmass, massive to slightly vesicular. +10F: 2% unaltered light green olivine phenocrysts (up to 0.5 mm); groundmass locally altered.	415–425	6279.3–6269.3
	Olivine basalt, medium-dark gray (N4), slightly porphyritic with aphanitic groundmass, massive to slightly vesicular. +10F: 2% olivine phenocrysts (up to 0.5 mm), oxidized to replaced; groundmass partly altered; fractures and vesicles thinly coated with iron oxide.	425–430	6269.3–6264.3
	Basalt / Scoria, dark gray (N3), aphanitic to very slightly porphyritic, aphanitic groundmass, very vesicular (scoriaceous). +10F: scoriaceous texture, most chips and fragments oxidized and/or coated with iron oxide.	430–440	6264.3–6254.3
	Olivine basalt, medium gray (N5), slightly porphyritic with aphanitic groundmass, massive to slightly vesicular. +10F: 1–2% olivine phenocrysts (up to 1.0 mm), opaque, replaced by iddingsite; groundmass strongly altered.	440–450	6254.3–6244.3
	Olivine basalt, medium gray (N5), porphyritic with aphanitic groundmass, vesicular. +10F: thin flat chips (up to 1.5 cm); 2–4% olivine phenocrysts (up to 2.0 mm), opaque, replaced by iddingsite; groundmass strongly altered throughout and bleached.	450–460	6244.3–6234.3
	Olivine basalt, light gray (N7), slightly porphyritic with aphanitic groundmass, massive, clay-sericite matrix binding chips together. +10F: 1–2% unaltered pale green olivine and dark opaque iddingsite-replaced olivine phenocrysts (up to 2.0 mm); groundmass strongly altered and bleached.	460–470	6234.3–6224.3
	Olivine basalt, light gray (N7), slightly porphyritic with aphanitic groundmass, massive, clay-sericite matrix binding chips together. +10F: 1–2% olivine phenocrysts (up to 2.0 mm), most are dark opaque and iddingsite-replaced; groundmass strongly altered throughout; 10–15% oxidized scoria from 475 to 480 ft bgs.	470–480	6224.3–6214.3
	Olivine basalt, medium gray (N5), porphyritic with aphanitic groundmass, massive to slightly vesicular. +10F: 2–3% olivine phenocrysts (up to 2.0 mm), partly to wholly replaced by iddingsite; groundmass moderately to strongly altered; 15–20% oxidized scoria from 485 to 490 ft bgs.	480–490	6214.3–6204.3
	No cuttings returned and no samples collected in this interval.	490–785	6204.3–5909.3
	Basalt, light gray (N7), aphyric, aphanitic, massive. +10F: 90–95% aphyric volcanic rock, feldspar-rich, altered and bleached; 5–10% white-cemented quartz sandstone. Note: this volcanic rock may be more siliceous than basalt.	785–790	5909.3–5904.3

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tb4 Cerro del Rio Basalt	Basalt, medium light gray (N6) to medium gray (N5), aphyric, aphanitic, massive. +10F: aphyric volcanic rock, abundant plagioclase laths, fine hornblende laths present, relict Fe-Mg minerals (up to 0.5mm) replaced by limonite, moderate to strongly altered, bleached appearance.	790–810	5904.3–5884.3
	No cuttings returned and no samples collected in this interval.	810–820	5884.3–5874.3
	Basalt, medium gray (N5), aphyric, aphanitic, massive. +10F: chips altered and bleached, trace of hornblende phenocrysts.	820–825	5874.3–5869.3
	No cuttings returned and no samples collected in this interval.	825–835	5869.3–5859.3
	Basalt/scoria, medium gray (N5), aphyric, aphanitic, massive to scoriaceous. +10F: chips slightly altered; groundmass contains felted plagioclase and trace of fine hornblende phenocrysts (up to 0.5 mm). +35F: 40–70% scoria fragments, white clay commonly filling vesicles. Vesicularity not observed in +10F.	835–845	5859.3–5849.3
	Basalt/scoria, medium gray (N5), aphyric, aphanitic, massive to scoriaceous. +10F: 90–95% massive, altered volcanic rock; 2–10% scoria. +35F: 50–60% massive volcanic rock; 40–50% black scoria cinders; 2–3% white clay.	845–860	5849.3–5834.3
	Basalt/scoria/sediments, medium gray (N5). +10F: 60–70% massive aphyric altered volcanic rock; 15–25% lithic fragments of dacite, pumice, and volcanoclastic sandstone, subangular to subrounded (up to 1.0 cm); 10–15% scoria. +35F: 55–65% scoria; 35–45% various volcanic rock fragments; 1–2% white clay.	860–870	5834.3–5824.3
	Basalt/scoria/sediments, medium gray (N5). +10F: 60–70% massive, aphyric altered volcanic rock; 15–25% lithic fragments of dacite, pumice, and volcanoclastic sandstone, subangular to subrounded (up to 1.0 cm); 10–15% scoria. +35F: 55–65% scoria; 35–45% various volcanic rock fragments; 1–2% white clay.	870–880	5824.3–5814.3
	Basalt/scoria/sediments, medium dark gray (N4). +10F: 50–65% scoria, locally clay-coated and with amygdaloidal clay; 20–30% massive, altered basalt; 10–15% lithic fragments of dacite, subangular to subrounded; 1–2% white clay.	880–895	5814.3–5799.3
	Scoria/sediments, medium dark gray (N4). +10F: 55–65% scoria, locally clay coated; 30–35% lithic fragments of dacite and various volcanic rocks, subangular to subrounded (up to 0.7 cm); <5% massive basalt; 1–3% quartzite and granitic lithic fragments; 1–2% white clay.	895–910	5799.3–5784.3
	Scoria/sediments, medium dark gray (N4). +10F: 55–60% scoria; 35–40% lithic fragments of dacite and various volcanic rock; trace of quartzite.	910–915	5784.3–5779.3
	No sample recovery in this interval.	915–920	5779.3–5774.3

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tb4 Cerro del Rio Basalt	Scoria, dark gray (N3), WR F: 85–90% black and gray (altered and bleached) scoria; 10–15% dacite lithic fragments; minor amounts of pumice and white clay. +10F: 85–90% scoria; 10–15% dacite lithic fragments; trace of pumice.	920–925	5774.3–5769.3
	Scoria, dark gray (N3), WR F: 85–90% black and gray (altered and bleached) scoria; 10–15% dacite lithic fragments, pumice, and white clay. +10F: virtually no sample retained. Note: Tb4/Tpf contact estimated at 932 ft bgs.	925–935	5769.3–5759.3
Tpf, Puye Formation	Volcaniclastic sediments, medium-dark gray (N4). +10F: 50–60% dacitic clasts; 30–40% basalt fragments, massive and scoriaceous, locally subrounded clasts; 2–3% white cemented quartzose sandstone.	935–940	5759.3–5754.3
	Volcaniclastic sediments, medium-light gray (N6) gravel (GW), with clay, clasts broken to subrounded (up to 0.5 cm), 10–15% fines, clayey. +10F: 70–75% gray dacite, broken or subrounded; 25–30% clay-cemented sandstone. +35F: 90% volcanic clasts; 10% Precambrian lithic clasts.	940–945	5754.3–5749.3
	Volcaniclastic sediments, grayish and pink (5YR 7/2) gravel (GW) with clay +10F: broken fragments (up to 0.5 cm); 75–85% dacite fragments; 15–25% clay-cemented fine-grained sandstone, mixture of volcanic and quartz grains; 1–3% glassy scoriaceous basalt. +35F: 98% volcanic clasts, glassy beads of basalt common; 2% quartzite.	945–955	5749.3–5739.3
	Volcaniclastic sediments, grayish and pink (5YR 7/2) gravel (GW) with clay and sand. +10F: broken fragments (up to 0.5 cm); 70–85% volcanic lithic fragments, mostly dacite with some basalt; 15–30% clay-cemented fine-grained volcanic sandstone. +35F: 96–97% volcanic clasts, 2–3% quartz/quartzite.	955–965	5739.3–5729.3
	Volcaniclastic sediments, grayish and pink (5YR 7/2) clayey gravel (GC), 25–30% clayey fines. +10F: broken chips (up to 0.5 cm); 97% gray and pink dacite clasts; 2–3% massive and scoriaceous basalt clasts. +35F: 98% volcanic clasts, trace of glassy basalt; 2% quartzite.	965–970	5729.3–5724.3
	Volcaniclastic sediments, grayish and pink (5YR 7/2) gravel (GW) with sand, 10–15% fines. +10F: broken chips (up to 0.5 cm) 99% dacite clasts; 1% basalt clasts. +35F: 97% dacite grains; 1–2% quartzite; 1% basalt.	970–980	5724.3–5714.3
	Volcaniclastic sediments, varicolored, gray and pink (5YR 7/2) gravel (GW) with clay. +10F: 80–85% dacite clasts; 5–10% basalt clasts; 5–7% clay-cemented volcaniclastic sandstone, broken and subangular clasts. +35F: no sample retained.	980–985	5714.3–5709.3
	Volcaniclastic sediments, varicolored, pinkish-gray (5YR 8/1) clayey gravel (GC) with sand. +10F: broken and subangular clasts (up to 0.5 cm); 60–70% dacite clasts; 15–25% clay-cemented volcaniclastic sandstone, numerous clay-coated clasts; 10–15% basalt clasts, partly glassy. +35F: 65–75% volcanic lithic clasts; 25–35% sandstone lithic clasts.	985–995	5709.3–5699.3

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tpf, Puye Formation	Volcaniclastic sediments, pinkish-gray (5YR 8/1) gravel (GW) with clay, clayey matrix, 10–15% fines. +10F: 60–70% broken and subrounded dacite clasts (up to 0.5 cm); 30–40% clay-cemented, fine-grained volcaniclastic sandstone clasts; trace of quartzite. +35F: 85–90% volcanic lithic clasts; 10–15% sandstone lithic clasts.	995–1005	5699.3–5689.3
	Volcaniclastic sediments, pinkish-gray (5YR 8/1) clayey gravel (GC) with sand, 20–30% fines. +10F: 60–70% broken and subangular dacite clasts (up to 0.3 cm); 25–35% clay-cemented, fine-grained volcaniclastic sandstone clasts; 1% basalt clasts; trace of quartzite. +35F: 85% volcanic lithic clasts; 10–15% sandstone lithic clasts.	1005–1015	5689.3–5679.3
	Volcaniclastic sediments, pinkish-gray (5YR 8/1) clayey gravel (GC) with sand, 20–30% fines. +10F: 80–90% broken and subangular dacite clasts (up to 0.3 cm); 10–20% clay-cemented, fine-grained volcaniclastic sandstone clasts; 1–2% quartzite, subrounded to rounded; <1% glassy basalt clasts. +35F: 99% dacite clasts; trace of glassy basalt clasts.	1015–1025	5679.3–5669.3
	Volcaniclastic sediments, pinkish-gray (5YR 8/1) gravel (GW) with clay and sand, 15–20% fines. +10F: 70–80% broken and subrounded dacite clasts (up to 1.3 cm); 20–30% clay and clay-cemented, fine-grained sandstone clasts; trace of quartzite. +35F: 99% dacite clasts; 1% quartz and sanidine grains.	1025–1035	5669.3–5659.3
	Volcaniclastic sediments, pinkish-gray (5YR 8/1) gravel (GW) with clay and sand, 15–20% fines. +10F: 75–80% broken dacite chips; 20–25% fragments of clay-cemented sandstone; <1% scoriaceous and glassy basalt. +35F: 99% dacite clasts; 1% quartz and sanidine grains; trace of basalt.	1035–1045	5659.3–5649.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) gravel (GW) with clay and sand, 15–20% fines. +10F: 80–90% broken to subangular light gray porphyritic dacite clasts; 10–20% clay-cemented, coarse-grained volcaniclastic sandstone; trace of basalt. +35F: 85–90% dacite clasts; 10–15% fine grained sandstone clasts; 1–2% quartz and sanidine grains; 1% glassy basalt clasts.	1045–1060	5649.3–5634.3
	Volcaniclastic sediments, pale yellowish-brown (10YR 6/2) gravel (GW) with silt and sand, WR: 60% gravel; 25% sand; 15% silt. +10F: mostly dacite clasts, some rounded (up to 7 mm); several clay-cemented, silty sandstone clasts; some rhyodacite clasts. +35F: mostly dacite clasts with some rhyodacite; 10% quartz grains.	1060–1070	5634.3–5624.3
	Volcaniclastic sediments, pale yellowish-brown (10YR 6/2) gravel (GW) with clay and sand, WR: 60% gravel; 25% sand; 15% fines, mostly clay. +10F: mostly dacite clasts, some subrounded (up to 1cm); some clay-cemented sandstone clasts; minor basalt and rhyodacite clasts. +35F: mostly dacite clasts; 5% quartz grains; 1–2% basalt clasts.	1070–1080	5624.3–5614.3

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tpf, Puye Formation	Volcaniclastic sediments, pale orange (10YR 8/2) gravel (GW) with clay and sand, WR: 50% gravel; 30% sand; 20% fines, mostly clay. +10F: mostly dacite clasts; some clay-cemented, silty sandstone clasts; minor rhyodacite clasts. +35F: mostly dacite clasts; some mafic clasts (basalt); 5–10% quartz grains.	1080–1090	5614.3–5604.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) gravel (GW) with clay and sand, 10–15% fines. +10F: Chips broken to subangular; 90–95% gray and pinkish dacite clasts, locally silicified; 5–7% clay-cemented sandstone; 1–3% altered pumice; trace of quartzite. +35F: 90–95% dacite clasts; 5–10% sandstone; 1–2% vitric basalt clasts.	1090–1100	5604.3–5594.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) gravel (GW) with clay and sand, 10–15% fines. +10F: Chips broken to subangular (up to 4 mm); 80–85% pink and gray dacite clasts; 10–15% clay-cemented, fine-grained tuffaceous sandstone; 7–10% altered pumice. +35F: 85–90% dacite clasts; 5–7% altered pumice; 3–5% fine-grained tuffaceous sandstone; 1–2% basalt clasts.	1100–1110	5594.3–5584.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) gravel (GW) with clay and sand, 10–15% fines. +10F: Chips broken to subangular (up to 5 mm); 85–90% monolithologic gray dacite clasts; 10–15% clay-cemented sandstone. +35F: 85–90% dacite clasts; 10–15% sandstone; 1–2% quartz and feldspar grains; trace of basalt clasts.	1110–1120	5584.3–5574.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) gravel (GW) with clay and sand, WR: 30–40% gravel; 30–40% sand; 10–15% fines. +10F: 90–95% monolithologic gray to pinkish dacite clasts, mostly broken chips; 3–7% fine-grained sandstone; 1% altered pumice. +35F: 90% dacite clasts; 10–15% sandstone; 1–3% pumice. Note: pumiceous fanglomerate interval from 1127 to 1242 ft bgs.	1120–1130	5574.3–5564.3
Tpp, Pumiceous Puye Fanglomerate	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) clayey sand (SC) with gravel, WR: 10–20% gravel; 50–60% sand; 20–30% fines. +10F: chips broken to rounded; 50–60% pinkish dacite clasts; 10–15% basalt clasts; 7–10% altered pumice; 5–7% clay-cemented sandstone; 3–5% quartzite clasts, rounded, gray with white acicular crystals.	1130–1135	5564.3–5559.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) clayey sand (SC) with gravel, WR: 15–25% gravel; 40–50% sand; 15–25% fines. +10F: chips broken to subrounded (0.5–1.5cm); 85–90% pinkish and gray dacite clasts; 3–4% quartzite clasts; 2–3% basalt clasts; 1–2% altered pumice. +35F: 97% volcanic lithic fragments; 3% Precambrian lithic fragments.	1135–1140	5559.3–5554.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) clayey sand (SC) with gravel, WR: 10–15% gravel; 40–50% sand; 25–35% fines. +10F: chips broken to subrounded (up to 0.4cm); 50–60% pink and gray dacite clasts; 15–20% basalt clasts; 15–20% white altered pumice; 2–4% rounded quartzite grains.	1140–1150	5554.3–5544.3

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tpp, Pumiceous Puye Fanglomerate	Volcaniclastic sediments, very pale orange (10YR 8/2) clayey sand (SC), WR: 7–12% gravel; 40–50% sand; 25–35% fines. +10F: chips broken to rounded (0.3 to 2.0cm); 50–60% gray and pink dacite clasts with some latite; 10–20% basalt clasts; 10–15% white altered pumice; 3–4% white rounded quartzite grains.	1150–1160	5544.3–5534.3
	Volcaniclastic sediments, very pale orange (10YR 8/2) clayey sand (SC), WR: 7–12% gravel; 40–50% sand; 25–35% fines. +10F: 25–50% white altered pumice; 20–25% dacite clasts; 10–20% basalt clasts; 1–4% white rounded quartzite grains.	1160–1170	5534.3–5524.3
	Volcaniclastic sediments, very pale orange (10YR 8/2) clayey sand (SC), WR: 7–12% gravel; 40–50% sand; 25–35% fines. +10F: Chips broken to generally subangular (0.3 to 1.0 cm); 60–75% gray to pinkish dacite clasts, some latite, locally flow-banded; 5–7% basalt clasts; 2–3% white altered pumice; 2–3% rounded quartzite grains; 1–2% clay-cemented, fine-grained sandstone.	1170–1180	5524.3–5514.3
	Volcaniclastic sediments, very pale orange (10YR 8/2) clayey sand (SC), WR: 10% gravel; 60–70% sand; 20–30% fines. +10F: Subangular to subrounded clasts (up to 0.4cm); 40–45% gray dacite clasts; 20–35% altered pumice; 10–15% subrounded to rounded quartzite clasts; 10–15% basalt clasts; 5–10% clay-cemented volcaniclastic sandstone.	1180–1190	5514.3–5504.3
	Volcaniclastic sediments, very pale orange (10YR 8/2) clayey sand (SC), WR: 10% gravel; 60–70% sand; 20–30% fines. +10F: broken to subrounded clasts (up to 0.3cm); 40–50% gray dacite clasts; 15–20% clay-cemented fine-grained volcaniclastic sandstone; 10–15% white clay-altered pumice; 5–7% basalt clasts; 3–5% rounded quartzite clasts.	1190–1200	5504.3–5494.3
	Volcaniclastic sediments, very pale orange (10YR 8/2) pumiceous clayey sand (SC), WR: 5–10% gravel; 60–70% sand; 25–35% fines. +10F: subangular to subrounded clasts (up to 0.3cm); 60–70% broken to subangular gray dacite chips; 25–30% white altered pumice; 7–10% basalt clasts; 1–3% quartzite grains.	1200–1205	5494.3–5489.3
	Volcaniclastic sediments, very pale orange (10YR 8/2) pumiceous clayey sand (SC), WR: 5–10% gravel; 60–70% sand; 25–35% fines. +10F: Sub angular to surrounded casts; 50–70% white and oranges tan altered pumice; 30–40% decide casts with minor ethereal quartz crystal, trace of manganese oxide; 10–15% basalt casts; 1–2% rounded quartzite grains.	1205–1215	5489.3–5479.3
	Volcaniclastic sediments, very pale orange (10YR 8/2) pumiceous clayey sand (SC), WR: 5–10% gravel; 50–60% sand; 20–30% fines. +10F: 50-70% white altered pumice; 35–45% volcanic lithic fragments, mostly gray dacite clasts with some basalt; 2–3% fine-grained sandstone; 1–2% quartzite grains.	1215–1225	5479.3–5469.3

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tpp, Pumiceous Puye Fanglomerate	Volcaniclastic sediments, very pale orange (10YR 8/2) pumiceous clayey sand (SC), WR: 5–10% gravel; 50–60% sand; 20–30% fines. +10F: 70–75% white clay altered pumice; 20–25% gray dacite clasts; 2–3% basalt clasts; 1–2% rounded quartzite grains.	1225–1240	5469.3–5454.3
Tsf, Santa Fe Group Sediments	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) clayey sand (SC). +10F: broken to subangular clasts (up to 0.3 cm); 35–45% gray dacite clasts; 20–30% pinkish fine-grained tuffaceous sandstone; 15–25% white clay-altered pumice; 5–10% scoriaceous basalt clasts; only a trace of quartzite. Note: Tpp/Tsf contact estimated at 1242 ft bgs.	1240–1250	5454.3–5444.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) sand (SW) with clay. +10F: mostly broken chips (up to 0.3 cm); 80–90% gray dacite clasts, broken to subrounded (up to 0.3 cm); 3–5% basalt clasts; 3–5% rounded quartzite grains; 1–2% white pumice; 1–2% fine-grained sandstone.	1250–1255	5444.3–5439.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) sand (SW) with clay. +10F: mostly broken chips (up to 0.3 cm); 80–85% dark gray dacite clasts; 3–5% subrounded to rounded quartzite grains; 3–5% white altered pumice; 2–3% fine-grained sandstone; 2–3% scoriaceous basalt clasts.	1255–1265	5439.3–5429.3
	Volcaniclastic sediments, light brown (5YR 6/4) sand (SW) with clay and gravel. WR: 10–15% gravel; 60–70% sand; 10–15% fines. +10F: mostly broken chips (up to 0.3 cm); 70–75% gray dacite clasts; 7–12% pink siliceous porphyritic rhyodacite clasts with phenocrysts of biotite, hornblende, and quartz; 3–5% quartzite grains and few other granitic clasts; 2–3% pumice; 1–2% fine-grained sandstone. +35F: 10–15% quartzite.	1265–1275	5429.3–5419.3
	Volcaniclastic sediments, light brown (5YR 6/4) sand (SW) with clay and gravel. +10F: broken to subrounded chips (up to 0.3 cm); 80–85% pink to gray dacite clasts and some pinkish rhyodacite; 2–3% rounded quartzite grains; 2–3% white pumice; 2–3% fine-grained tuffaceous sandstone; 1–2% scoriaceous basalt.	1275–1290	5419.3–5404.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) clayey sand (SC) with gravel. +10F: 85–90% volcanic lithic fragments, mostly dacite with some rhyodacite and minor basalt; 2–3% fine-grained tuffaceous sandstone; 2–3% pumice; 2–3% rounded quartzite grains.	1290–1300	5404.3–5394.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) sand (SW) with clay. +10F: subangular to subrounded chips (up to 0.3 cm); 95–97% volcanic lithic fragments, mostly dacite with some rhyodacite and minor basalt; 2–3% quartzite grains; 1% pumice.	1300–1305	5394.3–5389.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) sand (SW) with clay. +10F: broken to subrounded chips (up to 0.3 cm); 90–95% volcanic lithic fragments, mostly gray dacite with some pinkish rhyodacite and a trace of basalt; 5–7% quartzite grains; trace of pumice.	1305–1315	5389.3–5379.3

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tsf Santa Fe Group Sediments	Volcaniclastic sediments, grayish-orange (10YR 7/4) sand (SW) with clay. +10F: 95–97% volcanic lithic fragments, mostly dacite with some rhyodacite and a trace of pumice and basalt; 1–3% quartzite grains.	1315–1325	5379.3–5369.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) sand (SW) with clay. +10F: 92–96% dacite clasts, broken to subrounded chips (up to 0.3 cm); 2–4% quartzite grains; 1% pumice; trace of basalt.	1325–1330	5369.3–5364.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) sand (SW) with clay. +10F: 85–90% pink and gray dacite clasts, subangular to subrounded chips (up to 0.3 cm); 10–15% subrounded to rounded quartzite grains; 1–2% pumice.	1330–1345	5364.3–5349.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) sand (SW) with clay. +10F: 90–95% pink and gray dacite clasts, mostly broken chips; 4–6% subrounded quartzite grains; 1–2% altered pumice; trace of basalt.	1345–1350	5349.3–5344.3
	No sample return in this interval.	1350–1355	5344.3–5339.3
	Volcaniclastic sediments, grayish-orange pink (5YR 7/2) sand (SW) with clay. +10F: 85–90% pink and gray dacite clasts; 10–12% rounded quartzite grains; 1–3% pumice; trace of basalt; trace of calcite.	1355–1365	5339.3–5329.3
	R-20 BOREHOLE COMPLETED AT 1365 FT BGS TOTAL DEPTH		

Notes:

- American Society for Testing Materials (ASTM) standards (D 2488-90: Standard Practice and Identification of Soils [Visual-Manual Procedure]) were used to describe the texture of drill chip samples for sedimentary rocks such as alluvium and the Puye Formation. ASTM method D 2488-90 incorporates the Unified Soil Classification System (USCS) as a standard for field examination and description of soils. The following standard USCS symbols were used in the R-20 lithologic log:
SW = Well-graded sand SM = Silty gravel CH = Clay, high plasticity
GW = Well-graded gravel GM = Silty gravel SC = Clayey sand
GP = Poorly graded gravel GC = Silt
- Cuttings were collected at nominal 5-ft intervals and divided into three sample splits: (1) unsieved, or whole rock (WR) sample; (2) +10F sieved fraction (No. 10 sieve equivalent to 2.0 mm); and (3) +35F sieved fraction (No. 35 sieve equivalent to 0.50 mm).
- The term *percent*, as used in the above descriptions, refers to percent by volume for a given sample component.
- Color designations such as hue, value, and chroma (e.g., 5YR 5/2) are from the Geological Society of America's Rock Color Chart.

Appendix D

*LANL Borehole Video Logs
(CD attached to inside back cover)*

Appendix E

*Schlumberger Geophysical Report/Montage
(CD attached to inside back cover)*

Appendix F

*Westbay™ Multi-Level Sampling Diagram
(CD attached to inside back cover)*

Appendix G

Waste Characterization Data



*Risk Reduction & Environmental Stewardship Division
Water Quality & Hydrology Group (RRES-WQH)*
PO Box 1663, MS K497
Los Alamos, New Mexico 87545
(505) 667-7969/Fax: (505) 665-9344

Date: November 7, 2002
Refer to: RRES-WQH: 02-417

Mr. John Young
Hazardous Materials Bureau
New Mexico Environment Department
P.O. Box 26110
Santa Fe, New Mexico 87502

Mr. Curt Frischkorn
Ground Water Quality Bureau
New Mexico Environment Department
P.O. Box 26110
Santa Fe, New Mexico 87502

**SUBJECT: NOTICE OF INTENT TO DISCHARGE, HYDROGEOLOGIC WORKPLAN
WELL R-20**

Dear Mr. Young and Mr. Frischkorn:

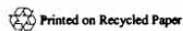
This week the Laboratory will begin discharging drilling water from Hydrogeologic Workplan Well R-20 in accordance with the Hydrogeologic Workplan Notice of Intent (NOI) submitted to your agency on August 2, 2001, and subsequently revised on July 16, 2002. Under the Hydrogeologic Workplan NOI, if drilling water produced from a Workplan Well is compliant with New Mexico Water Quality Control Commission (NM WQCC) Regulation 3103 ground water standards and applicable RCRA regulatory limits then the Laboratory can discharge without prior coordination with the NMED. Since the drilling water produced from Workplan Well R-20 meets the above requirements, the Laboratory is proceeding with land application.

The Laboratory containerized approximately 100,000 gallons of water produced during the drilling of Workplan Well R-20. Workplan Well R-20 is located on Pajarito Road southeast of Technical Area (TA)-18. Due to the presence of alluvial ground water in the vicinity of Workplan Well R-20 (alluvial water was observed from 9.5 ft. to 57.5 ft.), the drilling water will be applied to the road leading into Mortandad Canyon from TA-52. Depth to ground water at the land application site is approximately 1260 feet. As required by the Workplan NOI, no ponding, pooling, or run-off of the discharged water will be permitted. Information regarding the quality of the Workplan Well R-20 water is provided below.

Water Quality Data

Attachment 1.0 contains analytical reports (metals, general chemistry, perchlorate, nitrate, tritium, and high explosives) from the sampling of containerized drilling water from Workplan Well R-20. All samples were filtered (with the exception of total Hg) prior to analysis. Sample results are compliant with all NM WQCC Regulation 3103 ground water standards including the following contaminants of concern:

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Mr. Young and Mr. Frischkorn
RRES-WQH:02-417

- 2 -

November 7, 2002

Contaminants Of Concern	Screening Result (mg/L)	NM WQCC ground water standard (mg/L)
total Hg	ND	0.002
HE	ND	
tritium	ND	
Mn	0.013	0.2
perchlorate	ND	
nitrate (as N)	2.76	10.0

Please call me at (505) 667-6969 or Roy Bohn of the Laboratory's Environmental Restoration Project (RRES-R) at (505) 665-5138 if additional information is required.

Sincerely,



Bob Beers
Water Quality & Hydrology Group

BB/tml

Enclosures: a/s

Cy: M. Leavitt, NMED/GWQB, Santa Fe, NM, w/enc.
J. Davis, NMED/SWQB, Santa Fe, NM, w/enc.
J. Bearzi, NMED/HWB, Santa Fe, NM, w/enc.
J. Vozella, DOE/OLASO, w/o enc., MS A316
G. Turner, DOE/OLASO, w/enc., MS A316
M. Johansen, DOE/OLASO, w/enc., MS A316
B. Ramsey, RRES-DO, w/o enc., MS J591
K. Hargis, RRES-DO, w/o enc., MS J591
D. Stavert, RRES-EP, w/enc., MS J591
C. Nylander, RRES-GP, w/o enc., MS M992
S. Rae, RRES-WQH, w/enc., MS K497
D. Rogers, RRES-WQH, w/o enc., MS K497
M. Saladen, RRES-WQH, w/o enc., MS K497
J. McCann, RRES-WQH, w/o enc., MS M992
R. Bohn, RRES-R, w/enc., MS M992
D. Volkman, FWO-UI, w/o enc., MS K718
RRES-WQH File, w/enc., MS K497
IM-5, w/enc., MS A150

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ATTACHMENT 1.0

HYDROGEOLOGIC WORKPLAN
WELL R-20

CONTAINERIZED DRILLING WATER

ANALYTICAL REPORTS:

- GENERAL CHEMISTRY
 - METALS
 - PERCHLORATE
- NITRATE/NITRITE
 - HE
 - TRITIUM

Hydrogeologic Workplan Well R-20
Drilling Water Screening Results

ER

ER WATER SAMPLES

SAMPLE ID	DESCRIPTION	DATE MM/DD/YY	ER Req#	Ag ppm	Al Std.D. ppm +/-	As Std.D. ppm +/-	B Std.D. ppm +/-	Ba ppm
GW20-02-48099	R-20 mud, analyzed after filtering	09/12/02	1192S	<0.0003	0.25 0.01	0.023 0.001	0.090 0.001	0.049
GW20-02-48100	R-20 mud, analyzed after filtering	09/12/02	1192S	<0.0003	0.58 0.01	0.012 0.001	0.098 0.002	0.021

Hydrogeologic Workplan Well R-20
Drilling Water Screening Results

ER

SAMPLE ID	Std.D. +/-	Be ppm	Br ppm	Ca Std.D. ppm +/-	Cd ppm	Cl ppm	ClO3 ppm	ClO4 ppm	Co Std.D. ppm +/-	Cr Std.D. ppm +/-	Cs ppm	Cu ppm
GW20-02-48099	0.001	<0.002	<0.1	20.0 0.1	<0.001	11.2	<0.1	<0.01	<0.001	0.029 0.001	<0.003	0.026
GW20-02-48100	0.001	<0.002	<0.1	15.1 0.4	<0.001	12.2	<0.1	<0.01	<0.001	0.0082 0.0002	<0.003	0.025

Hydrogeologic Workplan Well R-20
Drilling Water Screening Results

ER

SAMPLE ID	Std.D. +/-	F ppm	Fe Std.D. ppm +/-	Hardness CaCO3 ppm	Hg Std.D. ppm +/-	K Std.D. ppm +/-	Li Std.D. ppm +/-	Mg Std.D. ppm +/-	Mn Std.D. ppm +/-
GW20-02-48099	0.001	0.65	0.07 0.01	56.4	0.0045* 0.0001	7.53 0.02	0.049 0.001	1.58 0.01	0.013 0.001
GW20-02-48100	0.001	0.60	0.19 0.01	48.8	0.0039* 0.0001	8.83 0.16	0.081 0.001	2.70 0.02	0.012 0.001

*REANALYSIS RESULTS: NON DETECT. SEE ATTACHED.

Hydrogeologic Workplan Well R-20
Drilling Water Screening Results

ER

SAMPLE ID	Mo Std.D. ppm +/-	Na Std.D. ppm +/-	Ni Std.D. ppm +/-	NO2 ppm	NO3 ppm	N total ppm	Oxalate ppm	Pb Std.D. ppm +/-	PO4 ppm	Rb Std.D. ppm +/-
GW20-02-48099	0.095 0.001	255 2	0.0065 0.0002	1.08	2.76	0.95	1.03	<0.0005	1.95	0.022 0.001
GW20-02-48100	0.097 0.002	274 1	0.0070 0.0001	0.73	2.62	0.81	1.04	0.0007 0.0001	3.26	0.013 0.001

Hydrogeologic Workplan Well R-20
Drilling Water Screening Results

ER

SAMPLE ID	Sb Std.D. ppm +/-	Se Std.D. ppm +/-	Si Std.D. ppm +/-	SiO2 calc ppm	SO4 ppm	Sn ppm	Sr Std.D. ppm +/-	Th Std.D. ppm +/-	Ti Std.D. ppm +/-
GW20-02-48099	0.0027 0.0001	0.005 0.001	23.5 0.1	50.3	237	<0.002	0.23 0.01	<0.001	<0.001
GW20-02-48100	0.0048 0.0001	0.003 0.001	18.0 0.1	38.5	229	<0.002	0.19 0.01	<0.001	0.005 0.001

Hydrogeologic Workplan Well R-20 Drilling Water Screening Results									
									ER
SAMPLE ID	Tl ppm	U Std.D. ppm +/-	V std.D. ppm +/-	Zn Std.D. ppm +/-	Acetate ppm	Formate ppm	comments		
GW20-02-48099	<0.002	0.011 0.001	0.032 0.001	0.003 0.001	+	+	unknown peak	before NO3	
GW20-02-48100	<0.002	0.011 0.001	0.015 0.001	0.004 0.001	+	+	unknown peak	before NO3	

Certificate of Analysis

Company : Los Alamos National Lab
 Address : PO Box 1663
 TA-3, Bldg. 271, Drop Pt. 01U
 Los Alamos, New Mexico 87545
 Contact: Keith Greene
 Project: Groundwater Project

Report Date: October 24, 2002

Page 1 of 1

Client Sample ID: GW20-02-49610 10
 Sample ID: 68196001
 Matrix: Ground Water
 Collect Date: 01-OCT-02 00:00
 Receive Date: 03-OCT-02
 Collector: Client

Project: LANL00401
 Client ID: LANL004

Parameter	Qualifier	Result	DL	RL	Units	DF	Analyst	Date	Time	Batch	Method
Mercury Analysis Federal											
7470 Cold Vapor Hg Liquid											
Mercury	U	ND	0.0472	0.200	ug/L	1	NOR1	10/22/02	1214	207403	1

The following Prep Methods were performed

Method	Description	Analyst	Date	Time	Prep Batch
SW846 7470A Prep	EPA 7470A Mercury Prep Liquid	KHN	10/21/02	1630	207402

The following Analytical Methods were performed

Method	Description	Analyst Comments
1	SW846 7470A	

Notes:

The Qualifiers in this report are defined as follows :

- < Actual result is less than amount reported
- > Actual result is greater than amount reported
- B Analyte found in the sample as well as the associated blank.
- BD Flag for results below the MDC or a flag for low tracer recovery.
- E Concentration exceeds instrument calibration range
- H Holding time exceeded
- J Indicates an estimated value. The result was greater than the detection limit, but less than the reporting limit.
- P The response between the confirmation column and the primary column is >40%D
- U Indicates the compound was analyzed for but not detected above the detection limit
- UI Uncertain identification for gamma spectroscopy.
- X Lab-specific qualifier - must be fully described in case narrative and data summary package
- Y QC Samples were not spiked with this compound.

The above sample is reported on an "as received" basis.

Where the analytical method has been performed under NELAP certification, the analysis has met all of the requirements of the NELAC standard unless qualified on the Certificate of Analysis.

This data report has been prepared and reviewed in accordance with General Engineering Laboratories, Inc. standard operating procedures. Please direct any questions to your Project Manager, Stacy Griffin.

Reviewed by _____

Certificate of Analysis

Company : Los Alamos National Lab
 Address : PO Box 1663
 TA-3, Bldg. 271, Drop Pt. 01U
 Los Alamos, New Mexico 87545
 Contact: Keith Greene
 Project: Groundwater Project

Report Date: October 24, 2002

Page 1 of 1

Client Sample ID: GW20-02-49611 10
 Sample ID: 68196002
 Matrix: Ground Water
 Collect Date: 01-OCT-02 00:00
 Receive Date: 03-OCT-02
 Collector: Client

Project: LANL00401
 Client ID: LANL004

Parameter	Qualifier	Result	DL	RL	Units	DF	Analyst	Date	Time	Batch	Method
Mercury Analysis Federal											
7470 Cold Vapor Hg Liquid Mercury	U	ND	0.0472	0.200	ug/L	1	NOR1	10/22/02	1259	207403	1

The following Prep Methods were performed

Method	Description	Analyst	Date	Time	Prep Batch
SW846 7470A Prep	EPA 7470A Mercury Prep Liquid	KHN	10/21/02	1630	207402

The following Analytical Methods were performed

Method	Description	Analyst Comments
1	SW846 7470A	

Notes:

The Qualifiers in this report are defined as follows :

- < Actual result is less than amount reported
- > Actual result is greater than amount reported
- B Analyte found in the sample as well as the associated blank.
- BD Flag for results below the MDC or a flag for low tracer recovery.
- E Concentration exceeds instrument calibration range
- H Holding time exceeded
- J Indicates an estimated value. The result was greater than the detection limit, but less than the reporting limit.
- P The response between the confirmation column and the primary column is >40%D
- U Indicates the compound was analyzed for but not detected above the detection limit
- UI Uncertain identification for gamma spectroscopy.
- X Lab-specific qualifier - must be fully described in case narrative and data summary package
- Y QC Samples were not spiked with this compound.

The above sample is reported on an "as received" basis.

Where the analytical method has been performed under NELAP certification, the analysis has met all of the requirements of the NELAC standard unless qualified on the Certificate of Analysis.

This data report has been prepared and reviewed in accordance with General Engineering Laboratories, Inc. standard operating procedures. Please direct any questions to your Project Manager, Stacy Griffin.

Reviewed by _____

Certificate of Analysis

Company : Los Alamos National Lab
 Address : PO Box 1663
 TA-3, Bldg. 271, Drop Pt. 01U
 Los Alamos, New Mexico 87545
 Contact: Keith Greene
 Project: Groundwater Project

Report Date: October 16, 2002

Page 1 of 2

Client Sample ID: GW20-02-49610 13/14/15
 Sample ID: 68195001
 Matrix: Ground Water
 Collect Date: 01-OCT-02 00:00
 Receive Date: 03-OCT-02
 Collector: Client

Project: LANL00401
 Client ID: LANL004

Parameter	Qualifier	Result	DL	RL	Units	DF	Analyst	Date	Time	Batch	Method
HPLC-EXPL Federal											
<i>HEXP / HEXPU</i>											
1,3,5-Trinitrobenzene	U	ND	0.249	1.04	ug/L	1	JLW	10/08/02	2027	206481	1
2,4,6-Trinitrotoluene	U	ND	0.779	1.04	ug/L	1					
2,4-Dinitrotoluene	U	ND	0.349	1.04	ug/L	1					
2,6-Dinitrotoluene	U	ND	0.501	1.04	ug/L	1					
2-Amino-4,6-dinitrotoluene	U	ND	0.779	1.04	ug/L	1					
4-Amino-2,6-dinitrotoluene	U	ND	0.409	1.04	ug/L	1					
HMX	U	ND	0.779	1.04	ug/L	1					
Nitrobenzene	U	ND	0.131	1.04	ug/L	1					
RDX	U	ND	0.530	1.04	ug/L	1					
Tetryl	U	ND	0.320	1.04	ug/L	1					
m-Dinitrobenzene	U	ND	0.330	1.04	ug/L	1					
m-Nitrotoluene	U	ND	0.640	1.04	ug/L	1					
o-Nitrotoluene	U	ND	0.640	1.04	ug/L	1					
p-Nitrotoluene	U	ND	0.640	1.04	ug/L	1					

The following Prep Methods were performed

Method	Description	Analyst	Date	Time	Prep Batch
SW846 8330 PREP	8330 EXPLOSIVES BY HPLC Prep in liquid	GMS	10/07/02	1000	206479

The following Analytical Methods were performed

Method	Description	Analyst Comments
1	SW846 8330	

Surrogate recovery	Test	Recovery%	Acceptable Limits
1,2-dinitrobenzene	HEXP / HEXPU	0%*	(59%-118%)

Notes:

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- > Actual result is greater than amount reported
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- E Concentration exceeds instrument calibration range
- H Holding time exceeded
- J Indicates an estimated value. The result was greater than the detection limit, but less than the reporting limit.

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 Contact: Keith Greene
 Project: Groundwater Project

Report Date: October 16, 2002

Page 1 of 2

Client Sample ID: GW20-02-49611 13/14/15
 Sample ID: 68195002
 Matrix: Ground Water
 Collect Date: 01-OCT-02 00:00
 Receive Date: 03-OCT-02
 Collector: Client

Project: LANL00401
 Client ID: LANL004

Parameter	Qualifier	Result	DL	RL	Units	DF	Analyst	Date	Time	Batch	Method
HPLC-EXPL Federal											
<i>HEXP / HEXPU</i>											
1,3,5-Trinitrobenzene	U	ND	0.249	1.04	ug/L	1	JLW	10/08/02	2110	206481	1
2,4,6-Trinitrotoluene	U	ND	0.779	1.04	ug/L	1					
2,4-Dinitrotoluene	U	ND	0.349	1.04	ug/L	1					
2,6-Dinitrotoluene	U	ND	0.501	1.04	ug/L	1					
2-Amino-4,6-dinitrotoluene	U	ND	0.779	1.04	ug/L	1					
4-Amino-2,6-dinitrotoluene	U	ND	0.409	1.04	ug/L	1					
HMX	U	ND	0.779	1.04	ug/L	1					
Nitrobenzene	U	ND	0.131	1.04	ug/L	1					
RDX	U	ND	0.530	1.04	ug/L	1					
Tetryl	U	ND	0.320	1.04	ug/L	1					
m-Dinitrobenzene	U	ND	0.330	1.04	ug/L	1					
m-Nitrotoluene	U	ND	0.640	1.04	ug/L	1					
o-Nitrotoluene	U	ND	0.640	1.04	ug/L	1					
p-Nitrotoluene	U	ND	0.640	1.04	ug/L	1					

The following Prep Methods were performed

Method	Description	Analyst	Date	Time	Prep Batch
SW846 8330 PREP	8330 EXPLOSIVES BY HPLC Prep in liquid	GMS	10/07/02	1000	206479

The following Analytical Methods were performed

Method	Description	Analyst Comments
1	SW846 8330	

Surrogate recovery	Test	Recovery%	Acceptable Limits
1,2-dinitrobenzene	HEXP / HEXPU	20% *	(59%-118%)

Notes:

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- E Concentration exceeds instrument calibration range
- H Holding time exceeded
- J Indicates an estimated value. The result was greater than the detection limit, but less than the reporting limit.
- P The response between the confirmation column and the primary column is >40%D

Certificate of Analysis

Company: Los Alamos National Lab
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 Los Alamos, New Mexico 87545
 Contact: Keith Greene
 Project: Groundwater Project

Report Date: September 23, 2002

Page 1 of 1

Client Sample ID: GW20-02-48099 02/03
 Sample ID: 67098001
 Matrix: Misc Liquid
 Collect Date: 12-SEP-02
 Receive Date: 14-SEP-02
 Collector: Client

Project: LANL00401
 Client ID: LANL004

Parameter	Qualifier	Result	DL	TPU	RL	Units	DF	Analyst	Date	Time	Batch	Mtd.
Rad Liquid Scint												
LSC, Tritium Dist, Liquid												
Tritium		-180	372	108	250	pCi/L		CAF1	09/20/02	1458	202687	1

The following Analytical Methods were performed

Method	Description
1	EPA 906.0

Notes:

TPU is calculated at the 67% confidence level (1-sigma).

The Qualifiers in this report are defined as follows :

- < Actual result is less than amount reported
- > Actual result is greater than amount reported
- B Analyte found in the sample as well as the associated blank.
- E Concentration exceeds instrument calibration range
- H Holding time exceeded
- J Indicates an estimated value. The result was greater than the detection limit, but less than the reporting limit.
- P The response between the confirmation column and the primary column is >40%D
- U Indicates the compound was analyzed for but not detected above the detection limit
- UI Uncertain identification for gamma spectroscopy.
- X Lab-specific qualifier - must be fully described in case narrative and data summary package

The above sample is reported on an "as received" basis.

This data report has been prepared and reviewed in accordance with General Engineering Laboratories, Inc.
 standard operating procedures. Please direct any questions to your Project Manager, Stacy Griffin.

Reviewed by

Certificate of Analysis

Company: Los Alamos National Lab
 Address: PO Box 1663
 TA-3, Bldg. 271, Drop Pt. 01U
 Los Alamos, New Mexico 87545
 Contact: Keith Greene
 Project: Groundwater Project

Report Date: September 23, 2002

Page 1 of 1

Client Sample ID: GW20-02-48100 02/03
 Sample ID: 67098002
 Matrix: Misc Liquid
 Collect Date: 12-SEP-02
 Receive Date: 14-SEP-02
 Collector: Client

Project: LANL00401
 Client ID: LANL004

Parameter	Qualifier	Result	DL	TPU	RL	Units	DF	Analyst	Date	Time	Batch	Mtd.
Rad Liquid Scint												
LSC, Tritium Dist. Liquid												
Tritium		184	381	121	250	pCi/L		CAF1	09/20/02	1629	202687	1

The following Analytical Methods were performed

Method	Description
1	EPA 906.0

Notes:

TPU is calculated at the 67% confidence level (1-sigma).

The Qualifiers in this report are defined as follows :

- < Actual result is less than amount reported
- > Actual result is greater than amount reported
- B Analyte found in the sample as well as the associated blank.
- E Concentration exceeds instrument calibration range
- H Holding time exceeded
- J Indicates an estimated value. The result was greater than the detection limit, but less than the reporting limit.
- P The response between the confirmation column and the primary column is >40%D
- U Indicates the compound was analyzed for but not detected above the detection limit
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Reviewed by _____